MINISTRY OF HEALTH.

THE PURIFICATION OF THE WATER OF SWIMMING BATHS.

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THE PURIFICATION OF THE WATER OF SWIMMING BATHS.

The provision and use of swimming baths has increased greatly in recent years. During the ten years from March, 1919, to March, 1929, loans have been sanctioned by the Ministry to a total of £3,164,955 for baths and washhouses; it is not practicable to state what part of this total is for swimming baths alone, but the figure gives some indication of the capital expenditure which has been undertaken since the end of the war.

It has thus become more important to take measures for assuring that the water of swimming baths shall be in a wholesome condition. The subject has received much attention in recent years; and a comprehensive report on it by officials of the Ministry is annexed.

Many improvements are practicable, and that often with a saving of cost. The report contains practical suggestions to this end. The principal requirements are an adequate filtration plant, but as simply contrived as possible, properly qualified supervision so as to make sure that the plant is being efficiently worked, and concise records, with close periodical scrutiny of them to test the results and the costs.

Ministry of Health,

August, 1929.

THE PURIFICATION OF THE WATER OF SWIMMING BATHS.

INTRODUCTION.

Swimming, a manly sport, has been extolled alike by poet and teacher. Locke, in his famous work on Education in 1693, says, "the advantages (besides that of swimming) to health by often bathing in the summer in cold water are so many, that I think nothing need to be said to encourage it."

Thomson* in 1727, in perhaps the noblest elegy of swimming yet written, praises not only swimming in summer but also in winter, even in the open air:—

"This is the purest exercise of health,
The kind refresher of the summer heats;
Nor, when cold winter keens the brightening flood,
Would I weak-shivering linger on the brink.
Thus life redoubles, and is oft preserv'd,
By the bold swimmer, in the swift illapse
Of accident disastrous. Hence the limbs
Knit into force; and the same Roman arm,
That rose victorious o'er the conquer'd earth,
First learn'd, while tender, to subdue the wave.
Even from the body's purity, the mind
Receives a secret sympathetic aid."

But to man, and especially to civilized man, swimming is not an inherited faculty, but an art won by laborious practice, and to acquire it he needs water of a safe and level shallowness, whilst to perfect it, together with the sister art of diving, he requires water of a safe depth.†

Whilst from forgotten ages he has found these opposite requirements either in the level sandy beaches and the precipitate rocks of the sea, or in rivers whose shallows alternated with deep pools, civilization long ago discovered the need for artificial swimming baths, the earliest known being the Piscina Publica, near the Circus Maximus, built in 312 B.C.‡, and supplied with water from the Appian aqueduct.

The earliest swimming bath§ in Britain of which we have

* James Thomson: "The Seasons," 1727: "Summer": line 1,256.

† Many baths are dangerously shallow for diving; seven feet six inches is required for complete safety with a diving board of any considerable height.

‡ J. Macpherson. Encycl. Brit. IX edit. iii, p. 434.

§ The interesting apse-headed oblong Roman Bath in Strand Lane, W.C.2 (15 ft. 6 ins. by 6 ft. 9 ins. by 3 ft. 6 ins.), is probably a large hot immersion bath rather than a swimming pool. Dating from about 120 A.D., it also is still water-tight, and fed by the original spring.

knowledge, viz., that in Bath, dating from the the first century A.D., has been preserved to us in ruins, still sublime in their massive grandeur, and with its pool, measuring 82 feet by 40 feet, still water-tight, and still fed by its original and perennial source which needs neither purification nor heat.

The latter end of the eighteenth century saw the beginning of the great revival of sea-bathing, which may be said to have begun in 1750 with the publication of a book by Dr. Richard Russell, of Brighton, on the remedial effects of sea bathing, and this revival of sea-bathing was followed by a new demand for swimming baths, hitherto only found in the palaces of the wealthy or at spas.

The first Baths and Washhouses Act was passed in 1846, enabling the Local Authorities to provide public baths and washhouses, including open-air swimming baths.

The Amateur Swimming Association was founded in 1869, and following the demand for greater swimming facilities, of which this Association was an expression, the Baths and Washhouses Act of 1878 empowered Local Authorities to provide covered swimming baths.

Prior to this amending Act all covered swimming baths in this country were privately owned. Mr. H. R. Austin* states that in the fifteen years 1875–1890 the number of establishments in England was doubled, 64 being added to the 63 built in the preceding 29 years. From 1890 he states that the yearly increase was about 8 per cent.

The first filtration and aeration plant for indoor baths was installed at Bury in 1905.†

Need for increased Swimming Facilities.

This century has seen an immense increase in popularity of swimming, and in the demand for swimming facilities, and the provision of such facilities still lags painfully behind the demand.

In some indoor pools of quite moderate dimensions, it is common, for example, to get 1,300 to 1,500 bathers in one day, and it is evident that under these circumstances the water can become con-

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* Proceedings at Annual Conference of Association of Bath Superintendents, 1925 (p. 6).

† Many years before this, however, a floating covered swimming bath, with a pool 135 ft. by 25 ft., holding 150,000 gallons, was moored in the Thames near Charing Cross Pier. This bath was filled by a continual flow of river water, pumped through a filtering apparatus (said to remove all suspended matter), heated and aerated by discharge in fountains. The pump and filtering apparatus could fill the bath in 6 hours ("Illustrated London News," July 19th, 1875, reference supplied by the kind researches of Mr. R. B. Wood, Librarian to the City of Westminster).

taminated to such an extent as to be below any reasonable standard of cleanliness.*

The general aspects of the problem of the provision of public baths and washhouses in the United Kingdom were summarized by Miss Agnes Campbell in 1918 in her report to the Carnegie United Kingdom Trust, to which the reader is referred for much detailed information regarding the provision of swimming baths in the United Kingdom.

Swimming is of immense service to the citizen. Its value from the life-saving and life-preserving standpoint requires no emphasis. The Registrar General's returns show that in England and Wales 1,589† lives are lost annually from accidental drowning, apart from suicide; some of these lives, no doubt, are those of swimmers, but many could have been saved had the victims been swimmers.

In the year 1926, 506 persons were reported to the Royal Humane Society as having been concerned in gallant rescues or attempts to rescue 524 persons from drowning.

But apart from this side of its usefulness, swimming is one of the best forms of exercise, exercising in the briefest time every muscle in the body, causing deep breathing, and immensely increasing the rate of metabolism.

The Chief Medical Officer of the Board of Education‡ states that "for the healthy child under suitable conditions, swimming is one of the best forms of exercise that he can practice, both in school days and subsequently. It is thoroughly enjoyable in itself, it provides vigorous exercise for the whole body without risk of over-development of any group of muscles, it promotes the full physiological activity of heart and lungs ; a good swimmer has always a well-built healthy body.

"Ultimately," he continues, "it is hoped that every school child will have an opportunity of learning to swim and will be taught to swim well.

"Meanwhile, any expansion of facilities for swimming instruction should be welcomed, and we should encourage every recognition

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* The following is a quotation from the Annual Report for 1925 of the Medical Officer of Health of a Lancashire County Borough. The pool referred to has a filtration plant with a "turnover" period of six hours. Under pressure of this extreme kind no purification can be rapid enough. The provision of other pools is the correct solution here. The Medical Officer states :—

> "After 4 p.m. on one day 750 boys were admitted, in addition to the ordinary bathers. It is quite common to get 1,300 to 1,500 bathers in one day. During six week-days no less than 7,000 bathers have attended the Baths. During the hot weather the capacity of the filtration plant is insufficient to keep the water in a reasonably clean condition, on account of the large number using the baths at these periods, and it is quite evident that the water in the plunge baths becomes contaminated to such an extent as to be below a reasonable standard of cleanliness."

† Average of five years 1923–1927.

‡ "Health of the School Child," 1926, p. 87.

of its value and practical usefulness as a recreational activity for both adults and child.

"Many local authorities fully appreciate the importance of instruction in swimming, and do what they can to encourage its development. Existing accommodation whether in open or covered public swimming baths or in school baths is insufficient to meet the needs of the school population."

Swimming is a powerful education factor for inculcating cleanliness and self-respect.

The unanimous agreement on this point of social workers in widely different localities is expressed by Miss Campbell in the report already cited.

> "As a means of learning and practising swimming, enjoying a healthy form of exercise and recreation, and aiding personal cleanliness, swimming baths are regarded, without exception, as a most valuable and important asset in the neighbourhood—an asset which many think would probably increase in value if the charges were decreased by 50 per cent." (London.)
>
> "They are undoubtedly a most valuable asset, and the only pity is that there are not more of them in this extensive and crowded Borough." (London.)
>
> "The value of swimming baths is recognised on all hands. Certain working girls' and boys' clubs have found extreme difficulty in securing an hour after working hours for club use; there is no doubt that one great problem is that, except for children in schools, the whole demand is in the limited number of evening hours after work." (Bristol.)
>
> "The swimming baths are very greatly used by men—factory workers, shop assistants, etc., etc." (Guildford.)
>
> "It is the opinion of those who have done social work in this district for many years that such an establishment would be a valuable asset." (Glasgow.)

Swimming, moreover, in cool water is of great value in hardening the body, and in enabling it to maintain its heat regulating mechanism in active function. This action is more effective in open air baths than in closed swimming pools, but in this climate, and in winter especially, the closed swimming bath is almost essential to enable the requisite amount of practice and exercise to be obtained. It is probable that, to persons who have made a habit of swimming, a regular daily swim throughout the winter is a potent aid in the prevention of chill, and of those commensal infections so constantly associated with chill. Swimming brings into full action not only heart, lungs and muscles, but also that great organ the skin, whose eliminative, heat-regulating, and other more subtle functions we are just beginning to understand, and whilst, as has already been said, the beneficial effect to the body of contact with cool water is immensely increased by the added effect of sunshine and the open air, yet the well-ventilated indoor pool of clean water has a great and indispensable place in the hygiene of urban life.

But, for the full achievement of all these benefits and pleasures of swimming, the water of the swimming pool must be of a high

quality. To induce many persons to bathe regularly, and to secure for all bathers healthful exercise in joy and safety, the pools must be full, not with dilute sewage, but with fresh, clear, and sparkling water, free from all harmful bacteria.

II. POLLUTION IN SWIMMING BATHS.

A. Sources not derived from the persons of the bathers.

These must be briefly noticed, although in this country at least where most indoor pools are filled in the first place with water drawn from public supplies, the contamination derived from the persons of the bathers is of chief importance for the purpose of this report.

(a) *Baths filled with already polluted water.*

In English swimming baths this has, so far, but rarely given trouble, the chief instance being that of the small epidemic of enteric fever at the Royal Marine Depot at Walmer, described by our late colleague, Dr. R. J. Reece, in a classic report to the Local Government Board in 1908. Here a swimming bath of some 60,000 gallons capacity was filled twice weekly with sea-water by tide pressure. The intake pipe of the bath was situated not much more than 100 yards and 500 yards respectively from two outfall sewers, from which sewage containing untreated enteric excreta was discharged. The water on filling the bath had the appearance of storm water in a London street after heavy rain.

Thirty-two cases of enteric fever occurred, of which 22 seemed to have been caused by infection from the bath water. Such a combination seems unlikely to occur in future, but the epidemic is worthy of remembrance in view of the increasing number of sea-water swimming pools now being provided at seaside resorts which are not always provided with purification apparatus.

Another epidemic was recorded by Jaeger in 1892 of 10 cases of severe diarrhoea or dysentery associated with *B. Proteus vulgaris* occurring in soldiers bathing in the River Danube, but the evidence is inconclusive, and the occurrence is only mentioned to show the extreme paucity of records of gastro-intestinal infections due to swimming in polluted water.

The waters of open air swimming places in the sea and in rivers are often slightly contaminated with sewage, but the pollution is diluted and, fortunately, the quantity of water swallowed by the bather whilst swimming is usually small.

(b) *Contamination from surface drainage, percolation, vegetation, etc.*

This is mainly seen in open air baths, particularly those with unlined sides and bottoms. In these, subsoil drainage percolating through, surface drainage from the immediate neighbourhood,

fallen leaves, dead animals, natural growths and water birds all contribute.

The green growths often complained of on account of appearance are, however, decidedly beneficial in large open ponds, as they purify the water from organic pollution by their powerful oxygenating action. Some of the London County Council's open ponds have been found to contain water super-saturated with dissolved oxygen to the extent of 192 per cent., i.e., 92 per cent. above what can be brought into solution by violent shaking or spraying of the water through air. These organisms thus do more in fact to purify waters than is possible by spraying the water through the air. In such large ponds as the Highgate and Hampstead ponds, which are seldom emptied, chemical analysis shows that little effect on the water is produced even by a large number of swimmers. At Hampstead the water was found to be more nearly saturated with oxygen in August, than in January.

In indoor baths, too, the growth of organisms already in the water may give trouble. Of these the principal are the green algae, which are very apt to flourish in waters from deep chalk wells, or in other waters containing considerable quantities of lime. Whilst alive the green algae are harmless, and may indeed keep up the oxygen saturation of the water, but they make the sides and bottom of the bath dangerously slippery, and impart an opaque green colour to the water. When growth is excessive, however, and the algae commence to die off, offensive tastes and smells may be caused.

The prevention of the growth of this type of organism sometimes requires heavy treatment by chloride of lime, although copper sulphate is perhaps the more usual treatment. This type of pollution, though aesthetically serious, is not dangerous to health, and is unlikely to occur in baths with efficient filtration.

(c) *Atmospheric Pollution.*

Dust and soot blowing in through the windows of baths (especially those which have been placed near refuse incinerators for the purpose of obtaining power and heat) form an uninviting scum on the surface of the bath when the water is at rest, which requires to be removed with scum rods. Deposit on the bottom of the bath may also take place. Despite the fact that the dust may contain considerable numbers of bacillus coli, this form of pollution, like the preceding, is more serious from an aesthetic than from a health point of view.

(d) *Boots.*

In swimming pools designed upon the lines usual in this country, a large proportion of filth found in the water is carried in from without by the boots of bathers, spectators and staff. The side paths of the pools are used by the bathers both for entrance to their boxes from the door, and for their subsequent entrance to the

water, and for walking round the baths in the intervals between swimming.

In consequence the side paths are almost always covered with visible dirt in suspension in water, and although drainage for these paths away from the pool is usually provided, a considerable quantity of pollution reaches the water on the bathers' feet. The only way to avoid this is to have entrances to the boxes or dressing rooms from outside separate from those by which the bathers enter the water. This requires a special design of bath house which has hardly been attempted in this country, except in some of the early privately-owned baths, such as Brill's at Brighton.

This arrangement may, with advantage, be combined with a system of shower or foot baths through which it is necessary for the bathers to pass from the dressing rooms before entering the pool.

(e) *Bathing Costumes.*

A large amount of pollution in swimming baths is derived from the costumes of the bathers. The State Board of Health of California state that the average number of bacteria found on a square inch of a bathing suit after use is approximately 150,000, but some costumes have shown more than one million per square inch. After proper cleaning not more than 500 bacteria per square inch should be found. Thorough washing in warm water with soap, followed by three rinses and some form of disinfection, must be followed by a thorough drying to make the articles entirely satisfactory for use. Towels have shown a bacterial contamination greater than that of costumes, as is only to be expected, and owing to the friction with the body which is employed in their use, proper cleansing, disinfection and drying are even more important in their case than in that of costumes.

B. Pollution derived from the Persons of the Bathers.

From the health point of view by far the most serious pollution is derived from the hair, skin, mucous membranes and urine of the bathers themselves.

Mucus from the nose, saliva from the mouth, sweat, dead epithelium, even from the cleanest bathers, dried secretions and accumulated dirt from the less clean, micturition (which is said to occur involuntarily in some persons on entering cold water), and even spitting, all add their quota to the pollution of bath water.

This pollution is of three kinds (1) particulate matter, including sometimes fragments of recently discharged mucus, (2) matters in solution, and (3) bacterial pollution, which may be considerable, even in waters which appear attractive.

All these three kinds of contamination are continually added by bathers, and the presence of the first two has, in addition, the effect of gradually converting the water into a culture medium, in which most of the bacteria introduced are able to undergo rapid

multiplication at the temperature (about 72° F.) at which indoor swimming baths are usually kept. These three forms of pollution require separate consideration. The first involves a rapid depreciation of the water, which soon becomes obvious to everyone, for untreated water, in which a large number of bathers relative to the quantity of water have bathed, rapidly becomes opaque, greyish black in colour, covered with film, and finally acquires an offensive smell.

A soluble pollution on the other hand may be of less importance, and in baths which are efficiently filtered and sterilised, there can be a considerable rise in such soluble constituents as nitrates and chlorides without effecting the usability of the water. Attempts have been made by chemical analysis to assess the soluble impurity imparted to the water of a swimming bath by each bather, and the report of the County Medical Officer of the London County Council in 1927 furnishes an estimate that each "not very clean" adult bather imparts 0·8 grammes of nitrogen in all forms, and 1·3 grammes of chlorides* to the water in which he swims. It is probable that this soluble impurity could be considerably reduced by the routine use of a preliminary shower bath, especially if the use of soap, followed by a thorough spray of clean water, were enforced, as is done in certain club swimming baths in this country and in many public baths abroad.†

The first form of pollution soon demands its own remedy, but the bacterial pollution, which is the most important, may be great without any obvious indication of its presence, and so requires special consideration.

C. Bacterial pollution of Swimming Baths.

As early as 1910, Drs. G. H. Pearce‡ and Sutherland published investigations upon the bacterial pollution of the public swimming bath at Batley in Yorkshire, where they reported bacterial counts in samples of the water ranging from 3,000 to 300,000 organisms per c.c. These were followed in 1912, by a paper§ describing work done by Dr. Graham Forbes, bacteriologist to the London County Council.

This paper was based on bacteriological examinations of the water from a small swimming bath in use at one of the London County Council's Industrial schools. The number of boys using the bath daily varied from one to two dozen, each boy washing himself all over thoroughly with soap before entering the water.

* In an analysis made for this report 0·5 grammes of chlorides per bather was the figure found for 440 bathers.

† It was, for example, enforced in the Public Baths at Pretoria as early as 1900.

‡ Lancet, 1910, ii., p. 542.

§ The Pollution of Swimming Baths, "School Hygiene," Vol. 3, No. 2, May, 1912.

The water was changed twice weekly, but no disinfectant was applied. The unpolluted water taken shortly after filling the cleansed bath yielded a count of about 100 organisms per c.c., chiefly of the *Proteus* group, whereas the samples obtained after the bath had been in use for two to three days gave an average of 4,000 organisms per c.c., among which *Streptococcus faecalis*, *Staphylococcus pyogenes aureus*, *B. coli communis*, *Proteus*, as well as gram-negative diplococci occurring in normal saliva, and certain skin contamination, were isolated and identified, alike from the polluted water and the slime deposited on the floor and sides of the empty bath.

These papers led to the formation of a Committee of the Royal Sanitary Institute, whose report was published in November, 1912. In January, 1917, Dr. W. A. Manheimer published a paper* comparing the methods for disinfecting swimming pools. This paper has been followed by many others in America, notably the report† of the Special Committee on bathing places by the American Public Health Association, in November, 1921, which has borne considerable fruit in the United States.

Dr. G. Forbes‡ has recently again reviewed the subject, and his paper and excellent recent papers by Dr. W. L. Mallman§ and Dr. G. K. Bowes|| should be referred to by all interested in the subject.

Sir Alexander Houston, in his Twentieth Annual Report to the Metropolitan Water Board 1926, p. 73, pointed out the possibility of the transmission of the leptospira of infective jaundice by swimming bath water, but added the reassuring information that this leptospira is very readily killed by means of chlorine, such doses as are normally used in chlorinated bath water being more than sufficient for this purpose.

Organisms Found.

As would be expected, the numerous bacteria found in the water of indoor swimming pools after use include the following—*Bacillus subtilis*, *B. prodigiosus*, *B. fluorescens liquefaciens*; faecal organisms such as *B. Coli*, *B. pyocyaneus*, *B. enteritidis sporogenes*, *B. proteus*; skin organisms, such as *Staphylococcus pyogenes aureus* and *epidermidis albus*; and organisms from the saliva, such as *Staphylococcus* and *Streptococcus salivarius*, and a gram-negative diplococcus (Graham Forbes).

It must be remembered that most of these organisms live in vast numbers as harmless parasites on healthy individuals, and only under exceptional circumstances become pathogenic; in other

* American Physical Education Review, 1917, January 22nd.
† American Journal of Public Health, 1922, 12, p. 121.
‡ The Journal of State Medicine, 1927, October, p. 595.
§ American Journal of Public Health, 1928, June, p. 771.
|| Journal of State Medicine, 1928, September, p. 521.

words they are "commensal"* and it is conceivable that "commensal" invisible viruses (such as that of herpes) and "commensal" protozoa such as leptospira might be found in swimming bath water. Dr. Wm. Royal Stokes,† using the specially filtered sediment from 2 gallons of bath water, and examining 500 colonies in pure culture, found that the only pathogenic organism present was *Staphylococcus albus*. His conclusion was that—

"While the above investigation lends practically no support to the theory of the transmission of infectious diseases by means of the pathogenic bacteria in the swimming pool, yet not enough tests have been made to render such a theory untenable. This can only be accomplished by the accumulation of a large number of totally negative results."

Dr. Griffith, by mouse inoculation, succeeded in isolating *streptococcus haemolyticus* from 20 c.c. of a badly polluted bath water (total count on agar at 37° C. in 2 days 18,000 per c.c.). This organism was specially sought for by this method on four occasions in connection with this report, but this was the only occasion on which it was found.

Bacterial counts as a measure of Pollution.

Water from an indoor swimming bath may afford the most varying bacterial counts, according to the number and cleanliness of the bathers who have used it and to the treatment which it has received. The temperature of the water, which usually lies between 70° and 74° F., has considerable influence upon the count, as might be expected, owing to the more rapid multiplication of most bacteria at the higher temperatures, whilst the temperature of the outside air appears also to exercise considerable influence, probably largely due to the increased secretion of sweat in hot weather on the persons of the bathers prior to bathing.

Pearce and Sutherland found counts of 300,000 organisms per c.c. growing on gelatine at 22° C. in water after 3 days' use by a total of 974 persons, mostly elementary school children. The same bath, on another occasion, after 4 days' use by a total of 938 persons gave a gelatine count of 63,000 organisms per c.c.

The gelatine count with bath waters is not, however, a satisfactory index, as has been pointed out by Thresh,‡ and confirmed by G. K. Bowes.§ Dr. Bowes§ gives the following example of gelatine counts (72 hours) in a bath of 62,000 gallons unprovided with purification plant.

1st day after use by 215 males	2,700
2nd day after use by 324 males and 63 females ..	347,000

* *i.e.*, organisms usually harmlessly parasitic, and only occasionally pathogenic invaders.

† Am. Jl. Pub. Health 1927, April, p. 334.

‡ Thresh and Beale "Examination of Waters and Water Supplies," 1925, p. 454.

§ Journal of State Medicine, 1928. Sept., 1928.

The agar counts at 37° C. for 48 hours of these two samples were 600 and 105,000 respectively, and in the first *B. Coli* was present in 50 c.c. and absent in 10 c.c., in the second present in 1 c.c. and absent in 0.1. In one bath, with a filtration plant but without chlorination, Bowes got the high gelatine count of 1,788,000 organisms per c.c., but there seems little doubt that in this case the filter was out of order.

Dr. Bowes' paper gives a record of careful work done in 1925 and 1926 on swimming baths in Birmingham, both with and without filtration plants, and it is worthy of close study.

His conclusions are similar to those at which we arrived by our investigation made in London in the following year. Dr. Bowes' work was unknown to us before its publication in September, 1928, and has afforded us welcome confirmation.

The Joint Committee on Bathing Places of the American Public Health Association in 1926* advised that the bacterial quality of swimming water should be determined by the following counts.

> *A*. Bacteria Count on Agar—2 days—20° C. (This count is optional.) Not more than 10 per cent. of samples covering any considerable period shall contain more than 100 bacteria per c.c. No single sample shall contain more than 200 bacteria per c.c.
>
> *B*. Bacteria Count on Agar or Litmus Lactose Agar—24 hours—37° C. Not more than 10 per cent. of samples covering any considerable period shall contain more than 1,000 bacteria per c.c. No single sample shall contain more than 5,000 bacteria per c.c.
>
> *C*. *B. Coli*—Presumptive Test. Not more than two out of five samples of 10 c.c. each, collected on the same day, or not more than three out of any ten consecutive samples collected on different dates shall show a positive presumptive test.

In some few of our own samples an agar count at 22° C. was made, but in most cases we relied upon the count on agar at 37° C. for 48 hours, and the determination of the presence of *B. Coli*. The same procedure was followed by Dr. Graham Forbes for the London County Council, whose results may be found in full in the Report of the County Medical Officer for 1927 (London), p. 38. Dr. Forbes states that 42 samples from five large open-air artificial pools without any process of filtration or chemical treatment were examined between 31st May and 21st October, 1926. The average count on agar at 37° C. for 48 hours for 1 c.c. of water was 950, the highest being 20,000 the lowest 1 per c.c. *B. Coli* was found in 1 c.c. in 19 of the 42 samples ; in 5 c.c. in 10 samples; in 10 c.c. in 3 samples; and absent from 10 c.c. in 10 samples.

We may contrast with these artificial open-air pools without treatment 26 samples taken by Dr. Forbes from 2 large open-air artificial pools with continuous filtration and chlorination. Seventeen samples from one bath showed an average count of 50 per 1 c.c. on agar, the highest being 500; but in 10 out of the 17 samples

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* American Journal of Public Health, XVI, 12th Dec., 1926, p. 1,200.

the total count was below 10 per c.c. *B. Coli* was absent in 12 of the 17; present in 10 c.c in 2 samples; in 5 c.c. in 2; in 1 c.c. in 1 sample (when the plant was not working).

Of the second large pool with continuous purification 9 samples (June to October) were taken; the average count on agar at 37° C. was 10, the highest being only 13, the lowest 4. *B. Coli* were present in 10 c.c. in 4 samples, in 5 c.c. in 1 sample (plant not working), absent from 10 c.c. in 4 samples. In 36 samples from three much used indoor pools with continuous filtration and chlorination the average count on agar at 37° C. was 150 per 1 c.c.; *B. Coli* was absent from 10 c.c. in 29 samples out of the 36; present in 10 c.c. in 3 samples; present in 5 c.c. in 2 samples. It must, of course, be remembered that one high count may seriously affect the average count.

Our own results from various baths in London and the neighbourhood showed great variations in count, and will be further discussed in relation to the various methods of purification.

Dr. W. L. Mallman, of Michigan,* has shewn that *B. Coli* multiply rapidly during the night in swimming baths, whilst streptococci do not. He therefore suggests that an estimation of streptococci by glucose and lactose broths forms a better index of pollution than the estimation of *B. Coli*. The conclusions of his paper are as follows:—

(1) *B. Coli* content is not a universally reliable indicator of intestinal pollution in swimming pools.

(2) *Streptococci* are constant indicators of intestinal pollution, and the number found in the pool parallels the amount of pollution as indicated by the numbers of bathers.

(3) *B. Coli* tend to multiply in the swimming pool, while streptococci do not.

(4) *Streptococci* when present indicate an unsafe condition of the swimming pool.

(5) *B. Coli* do not necessarily indicate pollution or danger, although the absence of *B. coli* is an excellent index of safety.

III. TRANSMISSION OF INFECTION BY THE WATER OF SWIMMING BATHS.

The evidence that various diseases are occasionally, though infrequently, transmitted by the water in swimming baths appears convincing.

Diseases occasionally thus conveyed fall into the following groups:—

Gastro-intestinal infections, respiratory infections, skin infections, eye infections, and nasopharyngeal infections, the last two

* American Journal of Public Health 1928, June, p. 771.

groups being by far the most numerous and important in this connection.

The first group, the *gastro-intestinal* infections, are seldom transmitted by swimming bath water for reasons which have already been referred to,* while it has already been said that the only recorded epidemics* were undoubtedly due to water grossly polluted by sewage.

In view of recent findings of *Leptospira* in London waters† it may be well to mention that no case of infective jaundice has, to our knowledge, been traced to infection by bath water. The reader is referred to Sir Alexander Houston's Twentieth Research Report, Metropolitan Water Board, 1926, p. 73.

Respiratory infections such as pneumonia, are occasionally described (Ogden), but it seems probable that such factors as too prolonged immersion, over-fatigue, and subsequent chilling, all tending to lower the resistance of the body of the bather to pneumococci which he is already carrying, are more important in the production of such a disease as pneumonia than infection by virulent pneumococci actually conveyed by the water.

Dr. H. M. Taylor‡ investigating the temperatures of 250 children who were allowed to stay in water of 73° F. for 45 minutes, found normal temperatures in 30, the remaining 220 all showing reduction in temperature, many exhibiting temperatures as low as 95° F. Unfortunately, no control series of similar children, not immersed in water, but engaging in exercise to the same degree as those immersed, is given. This question of lowered resistance by chilling, or by the excessive fatigue sometimes undergone by bathers unaccustomed to swimming, enters into the consideration of practically all swimming bath infections, the majority of which are due to those "commensal" organisms already described.§ As Professor J. J. van Loghem says, "whilst with every infection one has to take favouring (*i.e.*, resistance-lowering) circumstances into consideration—the further one goes in the direction of commensal infections, the more preponderating does the factor of circumstances appear."

The Skin infections which are occasionally associated with swimming baths such as furunculosis, scabies, ringworm and pediculosis, are probably usually transmitted by towels, costumes, and seats, rather than by water, despite the fact that organisms, potentially pathogenic to the skin, like *Staphylococcus pyogeneus aureus*, are often found in polluted bath waters. There is, however one important exception, furunculosis of the external ear, which seems generally to be due to auto-infection following irritation due to bath water retained by cerumen and skin casts in the external

* See page 9.
† Hindle, B.M.J. 1925, July 11th.
‡ Jl. American Med. Assocn. 1925, 85. 1. July 4th, p. 10.
§ see page 13.

ear. Erythemata and rashes due to chemicals used for purification have been described, but indicate gross over-dosage, which should never occur in a properly managed bath.

Conjunctivitis is the most common eye infection transmitted in swimming baths, and undoubtedly sometimes occurs in epidemic form. It is, however, perhaps more commonly spread by towels than by water, although it is undoubtedly sometimes caused by the water itself.

The reports of seven epidemics of conjunctivitis due to swimming baths were considered "reasonably authentic" by the American Special Committee on Bathing Places, but English and German opinion is less pronounced.

Several observers have called attention to a form of conjunctivitis, which is associated with nasal sinusitis and catarrh, and is said to have been transmitted in epidemic form in certain baths.

It must be remembered that, owing to the difference in composition between tears and bath water, any prolonged swim causes a slight mechanical or osmotic conjunctivitis, as may readily be observed, after a long swim, by looking at a distant light by night, when the light will be seen surrounded by a halo, due to slight conjunctivitis. Diving, underwater swimming, and swimming by a semi-submerged stroke, such as the "crawl," all tend to increase this condition.

Nasopharyngeal Infections.—Of the transmission of the ordinary infectious diseases (such as scarlet fever, measles, chickenpox, diphtheria) remarkably little is heard in relation to swimming baths. Remarkably little, that is, when the facilities for spread (other than by water) of such diseases afforded by the crowding of school children in the bathing hall, the queues in the corridors, and the dressing and undressing are considered.

Recently a small epidemic of scarlet fever in a public school was thought to have been caused in part by infection transmitted in the school swimming bath, and this seems possible as the bath is small and crowded, and the water was not frequently changed. Even so, the actual transmission of infection may not have been waterborne. Many of the indoor swimming baths of public schools are not provided with filtration and chlorination plant, and in some the water is not changed often enough. Such school baths do not afford shining examples of swimming bath hygiene, and the water is sometimes sadly polluted.

We have seen that it is possible, though difficult, to recover haemolytic streptococci from polluted bath water, so that the transmission by water of scarlet fever must be considered possible though improbable.

The late Dr. F. E. Batten suggested that the seasonal prevalence in hot dry months of epidemic poliomyelitis seemed to favour the idea that it might be associated with swimming bath pollution,

but the suggestion has received no confirmation in recent epidemics in this country or abroad.

As regards cerebro-spinal meningitis there appears to be equally little evidence incriminating the water of swimming baths as a medium for the transmission of infection. Two recent cases of cerebro-spinal meningitis in which the infection was alleged to have been contracted in baths at Acton, were enquired into by a medical officer of the Ministry, but the allegation was not substantiated. The meningococcus, the germ responsible for this disease, is a delicate one, which cannot long survive in cool water, it has never been experimentally isolated from swimming bath water, and the usual method of transmission is from person to person aerially, that is, by droplets of infected mucus passing direct from the nose or mouth of a "carrier" to the nose or mouth of the recipient during sneezing, coughing or even loud speaking at close quarters. Most people have sufficient natural immunity to this germ (a typical "commensal" organism, such as has already been described) to enable them to harbour it without sign or symptom of disease—they become for a short time, in technical terms, "healthy carriers," but in certain susceptible persons especially if their resistance be temporarily lowered from any cause, as by another, often minor, illness, or even by chilling or over fatigue the germ may succeed in passing from the nose to the blood stream and thence to the brain and spinal cord, and the disease, cerebro-spinal meningitis, may develop. Experience seems to indicate that in the few cases that are alleged to have occurred after swimming, the children are more likely to have been aerially infected from some carrier outside the bath water, and that the determining factor in such cases is the lowering of resistance

For the prevention of these and other diseases that are generally transmitted by droplet infection through the air, emphasis should be laid on the need for proper ventilation of the bath hall and the avoidance of overcrowding in the dressing boxes, as well as upon the purity of the water.

Nasal catarrh, sinusitis and tonsilitis.—Prolonged swimming in cool water, even when pure, causes an increase in the excretion of nasal mucus. A certain degree of turgidity of the nasal mucous membrane is probably caused. Some evolutions, such as "swallow" diving with the head over-extended, or turning over on to the back under water, will sometimes cause severe localized pain which may be evidence that water or mucus has been forced into the maxillary antrum. Dr. H. M. Taylor* has recorded numerous cases of sinusitis occurring in patients who had bathed in pure spring water (count not exceeding 150 bacteria per c.c.) at a temperature of 71° F. It is possible that, in crowded and unhygienic baths a particularly unfortunate bather might get

* Jl. Amer. Med. Assoc. 1925. S. 5. p. 7.

from the water a sufficiently massive dose of sticky mucus from another bather to infect him with a catarrh or a tonsilitis, yet it is probably a more usual sequence for the sufferer himself to be carrying the infecting organism already, and for the attack of catarrh or tonsilitis to be brought on by the abnormal state of the mucous membrane, or by the lowered resistance induced by unaccustomed and prolonged immersion, exertion, and chill. This is especially likely to be the case with tonsilitis, for we have seen how unusual it is to swallow any appreciable quantity of water. When we remember that the tonsils are constantly bathed in saliva, which contains normally some hundred million streptococci per c.c., and often contain in their crypts a multitude of pathogenic or potentially pathogenic germs (e.g., streptococci both of the haemolytic,* and of the viridans type), it seems unlikely that an infecting dose of another person's haemolytic streptococci would ever reach the tonsils. No epidemic of diphtheria has, to our knowledge, been ascribed to swimming bath infection, though waterborne diphtheritic nasal infection might seem theoretically possible.

Otitis.—But it is the ear infections which give the chief gravamen to the charge of disseminating disease against swimming baths. There are numerous recorded instances of middle ear disease undoubtedly following upon and obviously due to swimming, and in several cases recorded in the medical press of this country (and in one case known personally to one of us) mastoid disease, meningitis, and death have speedily followed the otitis media. The questionnaire of the American Special Committee on Bathing Places issued to 2,000 practitioners elicited details of 129 cases of otitis, 19 of mastoid disease, and 5 of meningitis, whilst the records of two epidemics of middle ear disease were considered by the Committee to be "reasonably authentic." It must be remembered, however, that there are estimated to be 15,000 swimming pools and places in the United States, so that the numbers of cases reported seem comparatively small.

In this country aurists have described epidemic waves of middle ear disease following swimming, occurring in hot summers such as 1921† and 1928, and have ascribed the disease to swimming bath infection.

Such cases are more likely to occur in persons who bathe infrequently and so run the maximum risk of infection for the following reasons. The bather who bathes infrequently is out of training for the particular exercise involved in swimming, and so becomes soon and greatly fatigued. His heat-regulating mechanism and his skin are alike unused to immersion in cool water, and he is very apt to chill. He is probably neither an expert diver nor

* Normal populations in cities may show a carrier rate of haemolytic streptococcus of 10 per cent., and carrier rates of 33 per cent. have been found in certain section of school populations.

† Dr. Dan Mackenzie, Lancet, 1921, ii, Sept. 10th, p. 589.

swimmer, and so is more likely to swallow water, to allow it to enter the nose, to cough or to choke. Moreover, he will most likely select the hottest weather for his unwonted swim, and so will encounter the most crowded period of the bath, and the most impure water. On the other hand, the bather who bathes regularly experiences no fatigue and no chill, is much less apt to swallow water, and probably being an expert swimmer tries to avoid hours when his swimming and diving might be impeded by crowds.

Admitting then that cases of otitis media are not infrequently due to bathing in swimming baths, we may ask what is the exact rôle of the water in causation? Is it the actual vehicle of infection transmitting the germs from the throat or ear of one bather to the middle ear of another bather, either by passage through an old perforation in the tympanum, or by the longer route of the naso-pharynx and eustachian tube? Or, on the other hand, is the water simply a mechanical agent, whose pressure forces already infected mucus from the nasopharynx up the eustachian tube, or is the "insult" of the cold water to the delicate mucous membrane sufficient to upset the drainage of the middle ear, or again, is it merely a matter of lowered resistance by chill (both local and general) and fatigue?

We do not know which of these is the usual way whereby swimming causes otitis media, but hydrostatic pressure is possibly the most important factor, pathogenic germs (particularly haemolytic streptococci) already "carried" by the patient, being forced by the pressure of water into the middle ear.

But the really extraordinary thing is that there are not more cases reported, when one considers the vast number who use swimming baths, among them being so many school children who attend baths as part of their curriculum, and are subject to medical supervision. In their case it would appear to be impossible that an outbreak of disease would not be traced to its source if a swimming bath was responsible for spreading infection on a large scale.

The German "Bäderstatistik" for 1913,* for example, stated that 96 indoor pools had had in one year 14,500,000 bathers, whilst to quote an English example† 89,430 male bathers used one pool in a year at Wigan. In 1928, on several consecutive days, over 2,000 bathers per day were recorded at one indoor swimming bath in London.

At public schools, otitis media is occasionally attributed to swimming in school baths where the water is of doubtful purity. No doubt such cases do occur, but as a rule infections of this kind are most prevalent in the early months of the year when there is no swimming.

* Quoted from Heberkel by G. M. Fair in Swimming Bath Sanitation. International Journal of Public Health, ii, 6, p. 631.

† Annual Report of Medical Officer of Health, Wigan, 1925.

The conclusions with regard to the possibility of infection by the water of swimming baths seem then to be as follows:—

(1) Although other factors are important, transmission of infection by polluted water can, and does, occur.
(2) Pathogenic bacteria can live in dirty bath water for considerable periods.
(3) It is desirable that the water of swimming pools should be free from pathogenic germs, and that its bacteriological count should approximate to that of drinking water. This standard of purity can best be maintained by the system of continuous purification—a combination, that is, of efficient continuous filtration, with continuous and accurately controlled chlorination.
(4) There is no evidence to support the alarmist rumours which appear from time to time, indicating that disease in epidemic form has its origin in swimming baths in this country.

IV. METHODS OF PURIFICATION OF BATH WATER.

Constant Flow.

The water of certain baths is constantly changed by a natural flow of water. Such are the numerous bathing places in rivers and certain indoor baths fed by strong springs. The most remarkable instances of these are the new swimming baths at Bath, where the water is maintained at a temperature of 83° F. by the admixture of cooled mineral water with the hot mineral water issuing at a temperature of 120° F., and the swimming baths at Buxton, which are directly over one of the principal springs issuing at a temperature of 82° F. through perforated marble slabs placed on the surface of the rock. Both are used for treatment purposes as well as for ordinary swimming, for which indeed they are somewhat warm. Matlock is fortunate in having an indoor swimming bath perpetually fed by a strong natural spring, which gushes from the hill-side at a constant temperature of 69° F., an ideal temperature for the physically robust swimmer.

Natural Purification.

Natural purification can be relied upon only when the pool is of great size, and receives sufficient spring water to compensate for evaporation, and to allow of the full development of the natural pond vegetation. The bathing ponds of Hampstead and Highgate depend mainly for their purification upon these natural processes, although there is a certain amount of change of water as well.

The bacterial analyses of these ponds show results better than would be anticipated.

Fill-and-Empty without treatment system.

This system, which was the only one in vogue during the 19th century, consisted in emptying the bath sometimes daily, sometimes every second day, and sometimes weekly, but generally at irregular intervals, according to the number of bathers. The bath is cleansed, scrubbed down, and washed out when empty. This system affords delightful water for the fortunate bathers who can bathe in the first few hours after refilling, but the depreciation of the water is very rapid, each successive bather adding his quota of contamination, and, except in slack times, it may be taken that the water of a swimming bath in the afternoon* after early morning refilling is inferior to the water of a bath, in which efficient treatment is provided, although the same water may have been in use for months. On the fill-and-empty system the criterion as to the necessity for refilling is almost always the appearance of the water, often entirely deceptive as regards the bacteriological impurity of the water. Moreover, owing to the length of time that refilling and heating takes, it is impossible to empty and refill during the day, whatever the number of bathers may be. The cost of filling a bath is considerable, and a superintendent may, for economy's sake, be tempted to allow a fair looking water to remain in the bath after one day's use. If the next day be suddenly hot, and a great number of bathers enter it, the water may be foul and offensive by the evening of the second day, and even dangerously opaque.

One of the chief objections indeed to the fill-and-empty system is the financial objection that it is difficult to fill and empty often enough owing to (1) the cost of the water, (2) of the fuel required to heat the cold water from the mains (say about 50° F.) to the bathing temperature of 72° F. usually desired in indoor pools, (3) of the larger and more expensive heating installation required, (4) of the extra wages for the night work entailed in cleaning the bath after emptying.

A further objection is the heavy draw involved in daily emptying upon the main supply in times of summer shortage. In many places this must curtail the frequency of changing.

Treatment by chemical means without filtration.

Many baths not provided with filtration plants are dosed at night after bathing has ceased with solutions of chloride of lime and other preparations of chlorine. A few are treated with copper sulphate in solution.

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* The following is an example—a bath of 42,000 gallons was emptied, cleansed and filled afresh with water from the mains in the early morning. A sample of the water was taken at 4 p.m. after use by 263 girls, mostly school children. The appearance of the water was still fair, a 19 wire gauge pin being visible at 5 ft. 6 ins. The bacteriological examination showed 6,500 colonies per 1 c.c. on agar at 37° C, and *B. Coli* present in 0·1 c.c., which was the smallest quantity tested.

This procedure, as it cloaks the inevitable appearance and masks the odour of deterioration, enables the same water to be used for a longer period without refilling, but it cannot be regarded as other than a doubtful expedient, and one that cannot be commended.

V. PURIFICATION BY CONTINUOUS FILTRATION.

The type of filter in general use for indoor baths is that commonly known as the Pressure Filter, although for outdoor, or large installations, the Rapid Gravity Filter is sometimes used, and the system closely resembles that found in many waterworks installations.

If the treatment is to be effective, the water in the bath should be circulated through the filter continuously while the bath is in use, and the success of a plant depends on the "*turnover period*" (i.e., the time in which the whole contents of the bath is passed through the filter) being sufficiently short.

Adverse impressions on the results obtained with filters may generally be traced to this period of turnover being too long. Early practice favoured 8, 9 or more hours, and the results were often favourable until a period of hot weather came which brought large numbers of hot, perspiring bathers to the bath, producing a "peak load." Then the plant failed, just at the time when it was most necessary that the water should be clean.

Various formulae have been put forward for calculating the turnover period which are based on the capacity of the bath in gallons, and the maximum number of bathers in a day, but they do not appear successful in practice.

Experience shows that for indoor baths which are largely frequented a turnover period of not more than four hours will keep the water clean during peak loads. Some bath superintendents in London favour a shorter period of 3½ hours in view of the advantages of having a little filtering capacity in reserve which enables them to show a crystal water for an evening gala even after heavy bathing during the day.

There are cases of baths which are out of the way and but little frequented, where a turnover period of 6 hours may be sufficient and economical, but it cannot be urged too strongly that four hours is the absolute minimum for a much frequented indoor bath which is to remain hygienic and popular by the attraction of clean water at all times.

It is a mistake to put in too small a battery of filters where there are several pools in the same bathing establishment on the assumption that the plant can be switched over from one pool to another. The size of the plant should be such as to give a turnover period of four hours or less for the total capacity of all the baths together. With this arrangement, however, it may be found convenient

occasionally to switch the whole plant on to one bath for a short period to get rid of some special contamination, such as discoloration by dye from new costumes.

For open-air baths, with fresh or sea water, the turnover period may generally be of longer duration, as such baths are generally of large capacity, and the "density" of bathers does not usually approach that found in indoor baths.

No general rule can be laid down for open-air baths; each case has to be considered on its merits, and it is wise in all cases to keep the turnover period as short as finances allow.

Description of the Process and Plant.

General.—Water is drawn from the deep end of the bath by a pump through a suitable strainer and, after the addition of coagulants to precipitate organic matter, and to ensure efficient filtration, is pumped to the top of the filter units.

The filter units consist of vertical or horizontal closed cylinders containing sand, and a system of collecting pipes at the bottom, which discharge the water after it has filtered through the sand. Means are provided for washing the sand from time to time by reversing the flow of water.

The filtered water is then warmed, aerated and chlorinated, after which it enters the bath through a number of inlets at the shallow end.

Suitable filters are manufactured by a number of makers, each of whom has evolved individual details in design.

In the early stages of bath filtration, the difficulty was to design plant which could be accommodated in the small and cramped spaces available in existing buildings built for the fill-and-empty system, and progress was handicapped to some extent by this restricted accommodation.

Now that ample space is provided for filters in the plans for new baths, it is hoped that makers will take advantage of the increased facilities to make improvements in design, which at present, under the influence of intense competition, shows signs of standardization to one general type which is not the most efficient in working costs, although the initial costs are low, and good results are generally obtained.

It is a sound principle of filtration to reduce the amount of matter to be removed by the filter to a minimum so that the filter is relieved and does not require frequent washing. This result might be best achieved by passing the chemically treated water through a coagulating tank where much of the suspended matter would be thrown down, as in the gravity type of rapid filter which is popular in waterworks practice, but there are no doubt great difficulties in adopting this system in connection with pressure filters.

Whilst the great majority of filter plants for swimming baths are of the pressure type, a consideration of the merits of rapid gravity filters for large installations, and especially for those in the open air, may be advantageous, as the initial and running costs are less than in the case of pressure filters above a certain size. Gravity rapid filters without a coagulating tank are, however, not to be recommended.

The success of a filter plant is, to a great extent, in the hands of the staff who control it, and for this reason it is essential that the amount of attention required should not be excessive, and the plant should be easy of access.

The architect who plans the building should provide ample space for the plant in a room which is well lighted, ventilated and free from dust.

The maker of the plant should see that all parts requiring attention are readily accessible, and that the plant is, as far as possible, fool-proof. Lubricators, for example, which need filling every few hours, or types of apparatus for adding chemicals which are easily blocked, should be avoided.

Outlet from Bath to Filter.—Outlets from existing baths are generally restricted to onesituated at the deepest part of the bath. For large new baths two or more outlets may be found necessary. Gratings of large area should be provided to minimise the effect of suction, and the slots or holes should not be large enough to entrap the finger of a diver at the deep end. According to the level of the pump, the water is drawn off by gravitation or suction through a cast iron pipe, which should be designed for a velocity of not more than 3 feet per second.

Strainer.—A strainer box is placed close to the pump and is isolated from the bath by a valve.

This strainer box should be readily accessible, and the flanged lid should be hinged, and attached by butterfly nuts. Strainers are intended to protect the pump, and should be of fine mesh or perforated metal, but of ample size to lessen friction losses. A duplicate strainer should be kept, and the ease of replacement of the strainer is an important point in design.

Pump.—This is the heart of the installation, and, if possible, should be in duplicate.

In the majority of cases the pump is of the direct coupled centrifugal type, driven by an electric motor. Sometimes direct acting steam pumps are used, but they are large and may cause pollution from oil, and it is doubtful if there is much gain in economy over a good design of modern electrically driven centrifugal pump. It must be remembered, however, that the pumping problem is not simple. A pump is required to deliver a constant volume of water per minute against a head which varies considerably from

the time when the filter is clean to the time when it has to be washed. The ordinary type of centrifugal pump will not deliver at a constant rate under these circumstances, but there are pumps which will comply very closely with the conditions. Unfortunately, owing to competition, the latter pumps, which are more efficient and slightly more costly, are neglected by filter makers, and, unless the engineers who draw up specifications for filter plant pay particular attention to the question of efficiency and running costs, there will be little progress.

Coagulants.

To secure efficient filtration at the desired rapidity, it is found necessary to use the ancient device of adding an aluminium salt, such as alum, or the less costly sulphate, or even alumino-ferric to the water.

This harmless chemical, purchased in slabs, is dissolved in water and added to the bath water as it passes to the filters in the proportion of one to two grains to the gallon of water to be filtered.

To fulfil its functions of forming a film upon the sand, the sulphate of aluminium has to react with an alkaline salt to form aluminium hydrate, a flocculent precipitate which forms a coat on the surface and also round the grains in the upper layer of sand and so arrests the passage of particular matter, and, to some extent of bacteria, thus enabling the filter to discharge clear water. The aluminium hydrate also has the property of attracting organic matter out of the water, and will thus reduce the bacterial content and also remove the brown colour from a peaty water, and the blue dye from costumes which sometimes discolours a bath water.

The alkaline salts referred to above are present in most hard waters in sufficient quantity to react with the sulphate of aluminium for a considerable period before they are exhausted. But in the case of soft waters it is necessary to add a small quantity of lime or soda ash, and provision should be made for doing this in all cases.

For efficient filtration the water must be slightly alkaline to methyl orange, but the important question of alkalinity will be discussed later.

The method of adding these chemicals requires special apparatus, many ingenious forms of which are supplied for the purpose. The usual practice has been to make up solutions of the two chemicals in tanks of sufficient capacity to last for a day's run. Tanks, fittings and pipes for sulphate of aluminium should be made of non-corroding material, as this chemical is slightly acid. Perhaps the best material for such tanks is slate, but the use of lead-lined tanks or wooden tanks is permissible. Pipes and fittings may be of lead, phosphor bronze or vulcanite, although the latter is rather liable to fracture. A good class of rubber hose has been used with success and has advantages. The tanks and pipes should be of *ample size* to obviate clogging in the latter, and to enable dilute

solutions to be used, as it is much easier to regulate the larger flow of a dilute solution than the mere trickle of a strong solution. Duplicate tanks should be provided so that solutions can be made up ready for the next day's work. Drip feeds from constant level tanks fed from the main tanks by means of ball cocks are unreliable and should be avoided. Perhaps the best, although the most expensive, means of adding the chemical solutions is to pump them by small ram pumps into the main leading to the filters. These pumps are made with a stroke which can be varied, and they are positive in action. Other methods are based on the use of a Venturi tube, some of these are simple and effective. It is essential that the apparatus provided for adding chemicals shall be of good design and easily worked. Any additional outlay on this part of the plant will be money well spent, for if the chemicals are not added regularly and exactly in accordance with the requirements of the water, good results from the filters cannot be expected.

Filters.

The filters themselves are usually mild steel cylinders with dished ends, and are used in both vertical and horizontal positions. The limiting diameter for transport appears to be 8 ft. 6 ins., which gives a vertical unit with a filtration area of 56·74 square feet.

The majority of manufacturers seem to have favoured the vertical design, but there are indications that horizontal units are being considered in order to save cost in large installations.

The pump delivers the water to which the coagulants have been added into the top of the filters and so through a layer of sand of varying thickness and grade according to the design. The old practice of making up the sand layer with beds of different graded sands is no longer exclusively favoured, as the agitation of the sand, and the upward washing have the effect of mixing up the beds. Similarly, the provision of costly crushed quartz sand is giving way to the cheaper and equally effective natural Leighton Buzzard sand.

The sand layer is supported on layers of graded gravel, and generally the arrangement of the filtering medium is similar to that found in the waterworks slow sand filter.

The water is collected from the bottom of the filter by a system of pipes with guarded orifices placed closely together.

At one time a great amount of stress was placed on the design of these orifices and strainers, and many ingenious and special arrangements were patented. The tendency of design is now in the direction of simplicity and cheapness with apparently no falling off in efficiency.

Strainer systems are usually embedded in concrete, to obviate the collection of dirt, or dead water at the bottom of the filter.

Washing the Filter.

Rapid filters differ from slow sand filters in that they are provided with a speedy method of washing sand. This is necessary, because washing may be required at intervals of a few hours, whereas the slow sand filter for waterworks frequently runs for months, before it needs cleaning.

To wash a rapid filter, two distinct processes are necessary :—

(1) Breaking up of the solidified sand bed by some form of agitation;

(2) Washing of the sand by means of an upward flow of water.

Many devices have been introduced to break up the sand bed, and there has been keen controversy as to the respective merits of such systems.

In the early days of rapid filters for waterworks purposes the use of rotating rakes worked by power was general, but this necessitated a circular design of filter of limited size, and the demand for large rectangular masonry filter units brought in the method of agitation by means of air admitted under pressure through the collecting orifices at the bottom of the bed.

Air agitation has been replaced by "high velocity wash" in the U.S.A., but, in this country, high pressure water for breaking up the sand, and for washing, has not found favour, as it is considered to be uneconomical in water consumption, and is attended with the risk of carrying away sand.

While the use of rotating rakes for circular filters is effective, the apparatus is costly and, in this country, most manufacturers have continued to develop the equally efficient method of air agitation.

A third method of breaking up the sand is found in a horizontal filter, which is rocked backwards and forwards on its axis.

Different makers of filter plant naturally praise the merits of their own particular designs, and it will perhaps suffice to say that the Ministry of Health does not discriminate between air and mechanical methods of agitation, both being effective for breaking up the sand bed.

For installations of any size, a power unit is required to work the agitation system, and in the case of rakes, the provision of shafting, gear and belts is a costly item.

Air for agitation is supplied by a compressor or blower according to the size of the plant, and, in plants where steam is available, a simple form of Korting air injector worked by a steam jet is effective. Where compressors are used it is essential to place an oil separator on the compressed air pipe to retain any waste oil from the compressor cylinder which might otherwise form an unsightly film on the bath water.

To wash a filter, the unit is isolated, and a connection at the top leading to waste opened.

The rakes are then worked for a few minutes, or air under pressure is turned on through the orifices at the bottom. After the agitation of the sand, water is passed upwards through it from a connection feeding the orifices at the bottom and, as soon as the dirty water flowing to waste is observed to be running clear, the operation is finished. The filter is then opened for unfiltered water from the top, but is not opened to discharge from the bottom for a few minutes as this delay allows the sand to settle down and to collect a little flocculent matter on the surface.

Washwater.

The supply of washwater in the case of bath filters is not difficult. In some cases it is possible to wash a unit with the filtered effluent from other units.

Another method is to wash direct from the water main, but the more usual procedure is to wash with bath water direct from the pump. The use of clean water from the main for washing filters is open to the objection that this fresh water is lost, and is not utilised to renew the much used bath water, or as a means of keeping up the natural alkalinity in the case of hard water.

Speed of Filtration.

The proper rate of filtration for swimming bath filters in terms of gallons per square foot of sand area per hour has been the subject of much discussion. Unfortunately, so far, few reliable data based on careful experimental work have been produced from which conclusions of any scientific value can be drawn.

Even in the case of pressure filters used for water supplies, the position is not much clearer, although it is known that, as the rate of filtration is increased, so the reduction of bacteria is lessened, and that it is unsafe to rely solely on this method of filtration where polluted waters are to be used for domestic supplies. In such cases the rate of filtration rarely exceeds 100 gallons per square foot per hour, and filtration is usually followed by chlorination.

If chlorination be considered necessary, why should such a low rate of filtration be adhered to ? The answer is that pressure filters worked at this low rate will give a fairly safe effluent at most times, and if the chlorine treatment fails by inattention, or from any other less likely cause, the danger to health is not very great. In water purification for domestic use, it is desirable that there shall be as many safeguards as are reasonably possible for the protection of the consumers.

It may be that in time a demand will arise for similar precautions in the case of swimming bath waters, but for the present it appears that purification of these bath waters may be undertaken with a reasonable degree of safety by means of methods which are less refined and less costly.

Water drawn from a swimming bath which has been used by bathers, generally contains bacteria in large numbers, and it is useless to hope that they can be eliminated, or even reduced to reasonably safe limits by filtration alone, under conditions which are possible at a bath establishment.

Continuous and effective chlorination has to be relied on to destroy these bacteria, and, if the chlorination breaks down, the risk of infection to bathers (which has been fully considered in the early part of this note) is present. The fact that chlorine treatment has, in any case, to be relied on to destroy the bacteria which the filters, designed for baths on lines now considered practicable, cannot eliminate, has led to high speeds of filtration up to 450 gallons per square foot per hour being used. It would appear that the limit of speed (in the absence of definite knowledge on the subject) should be such as to yield a clear water having a definite standard of clarity at all times, and under all conditions of bathing.

It may be of interest to state that the American Water Works Association, in their standard specification (1925), for pressure filters using a coagulant, lay down filtration rates for swimming pools of 2 to 4 U.S. gallons per square foot of sand area per minute. These rates are practically equivalent to speeds of 100 to 200 Imperial gallons per square foot of sand area per hour.

In this country the majority of makers favour a rate of 200 gallons per square foot per hour or less, but competition is having the effect of increasing rates above 200, and it is not yet clear what is the maximum rate permissible.

It is unfortunate that this question has not been settled by practical research because it is evident that economy of working (i.e., in power, chemicals, washwater and attendance) and speed of filtration must be related, while the important question of the maintenance of a standard of clarity in the filter effluent at all times has hitherto received scant attention. This subject is discussed later under the heading of Guarantees.

Re-heating.

The best method of re-heating is by the use of a calorifier, though it is sometimes done by the injection of steam. In the latter case, if exhaust steam from an engine be used in direct contact with the water, perfect elimination of oil is essential. From the point of view of economy it is one of the great virtues of the continuous purification method that the loss of heat involved is comparatively small, so that re-heating is inexpensive compared with the cost of the large quantity of fuel which is required, when operating a bath on the fill-and-empty system, to heat the whole volume of the fresh water from the temperature (about 50° F.) at which it enters the bath from the mains to the desired temperature of about 72° F.

Aeration.

Aeration of the water is an adjunct to filtration essential to make the used water satisfactory for re-use by bathers. Aeration is a natural method of purification of water, and too great importance cannot be attached to efficient aeration in connection with bath waters.

Some makers of filter plant advise that aeration should come before filtration, mainly with the idea of assisting and keeping sweet the filters. This is good practice, but it is now generally agreed that aeration should in all cases take place *after* filtration, even when the water has already been aerated before filtration. The chief reason for insisting on aeration *after* filtration is due to the fact that water may lose most of its dissolved air during its passage through filters.

The usual form of aerator is a closed chamber through which the water passes, and into which air is blown by means of a compressor or blower, or is sucked in through a nozzle.

More air is used than the water will take up, and means should be provided for the surplus air to discharge through a pipe led to the open air outside the filter house as objectionable gases might otherwise escape with it into the bath hall when the water reaches the pool.

Open-air baths are often fitted with a cascade or ornamental fountain in the grounds through which the water passes on its way to the bath. This system of aeration can be made efficient if attention is paid to the design, and the costly blowers or compressors which use a considerable amount of power can thus be dispensed with. In such cases (and indeed in most cases) it is advisable to chlorinate after aeration.

The usual method of supplying air for the aerator is by means of motor-driven blowers or compressors. An oil filter should be used to eliminate oil from the air, and care should be taken to see that the plant supplied is of ample dimensions to saturate the water, that it is not worked at excessive speed and has proper cooling arrangements.

For important installations, the duplication of this plant in view of the possibility of a breakdown should be considered.

VI. CHLORINATION.

In certain of the older plants, chlorination is performed before filtration, but there seems to be no doubt that the proper position of this process is after filtration, though whether it should precede or follow aeration is a matter upon which there is some difference of opinion.

Chlorination should always be a continuous process, and it is regrettable that, in many instances, filtration plants, originally

intended to run with continuous chlorination, have been allowed, mainly through difficulties with the mixing tanks and feed pipes, to degenerate (for there is no other word) into filtration systems in which chlorination is merely done nightly when bathing has ceased. Such intermittent chlorination can only be regarded as an unsatisfactory makeshift.

Chlorination after filtration in this country so far has been done by three methods :—

(1) The addition of bleaching powder in solution ;

(2) the addition of liquids such as "chloros" or "voxsan" or electrolytic fluid containing, as a rule, some 10 per cent. of free chlorine; and

(3) by the administration of chlorine gas in solution in water.

Perfectly satisfactory chlorination can be attained by any of these methods provided that the apparatus supplied is of proper design, that the chlorine content of the bleaching powder or solution can be relied on, and that skill, care, and continuous supervision are given to the administration. At the same time, the great variation in the "bathing load" and the consequent large variations in the pollution and so what is known as the "chlorine demand" of the water render the problem of efficient chlorination, without giving rise to complaints, by no means a simple one.

"Free" Chlorine Content.

Proper chlorination, therefore, involves accurate dosage, which must be capable of easy and rapid variation to meet the large variations in the incoming pollution, and so maintaining the correct amount of "free" chlorine in the water, after its "chlorine demand" has been satisfied. This in its turn involves the equipment of the staff responsible for the dosage with appliances sufficiently precise to give an estimation of the free chlorine, accurate between the limits required, and simple enough to be worked by a bath superintendent, who is not necessarily an expert chemist. Fortunately this requirement has now been met, and there are several easily worked apparatus upon the market of British manufacture by which a bath superintendent or the responsible engineer can at any time ascertain the free chlorine content of the pool, and of the effluent water.

We are in agreement with the recommendation of the American Committee that the free chlorine actually present in the water of the pool (not merely in the filtrate) should amount to not less than 0·2 and not more than 0·5 parts per million of water.

The maximum of 0·5 parts per million of free chlorine appears to us to leave a reasonable and sufficient margin of safety before complaints of smell of chlorine or smarting eyes begin. One of us

has repeatedly bathed in water containing as much as 1·3 parts per million, without detecting odour, or smarting, and without hearing of any complaints from fellow bathers. Such a strength is, however, unnecessary, and not to be recommended.

The chlorine gas process, in our opinion, admits of much more easy and accurate adjustment to meet the varying needs of the swimming pool, than either of the other two methods, and is, in our opinion, less liable to cause complaints, particularly as regards smarting of the eyes.

The following table shows that, from the point of view of neutralizing the bacterial pollution in a bath water, the presence of enough "free" chlorine in the water of the pool itself is the essential factor. The table shows the bacterial count of bacteria per c.c. growing on agar at 37° C. for 48 hours, together with the smallest quantity of water in which B. Coli was present, in samples taken from nineteen pools all furnished with modern filtration plant by various makers. In all cases samples were taken from the deep end of the pool (nearest point to the exit) about four in the afternoon on hot days, the pools being well filled with bathers. The number of persons who had bathed prior to the time of sampling on the day of sampling of course varied, but for the larger pools the average was about 400; for the smaller about 250, but the number was not the decisive factor in the count. The total number of bathers since the pool had been last refilled also varied, three of the best bacteriological samples being from pools in each of which some 50,000 bathers had bathed since the last emptying and refilling.*

The procedure was as follows :—a bacteriological sample was taken, and transported in an ice chest to the Ministry's laboratory, where within less than two hours, it was plated upon agar and inoculated into broth. Other samples from the same place in the pool taken at the same time, were tested on the spot by the orthotolidine method using six (or later eight) standard tints. Alkalinity and turbidity were also estimated. All the waters looked clear and attractive, and no complaints of smell or smarting eyes were encountered. In several cases where the free chlorine content was found to be high, personal experiment was made by bathing or by keeping the eyes in the stream of water from the filters (shallow end) with a view of detecting any effect upon the eyes—but with negative results.

In ten of the pools chlorination was continuous, i.e., the chlorine† was administered all the time that filtration and bathing were in progress (except of course when shut off on the free chlorine content becoming excessive).

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* Compare a similar series of results by W. H. McLain and G. E. Rickard in the swimming pools of Wheeling City, West Virginia, quoted by E. S. Tisdale, "American City," April, 1929, p. 114.

† In two cases by gas apparatus, in eight derived from bleaching powder.

Table Showing that the Maintenance of the Free Chlorine Content in the Water is the Main Factor in the Production of a Low Bacterial Count in Samples from Pools provided with Continuous Filtration Plants.

(Afternoon deep end samples from much used pools.) For explanation of table *see* page 34.

	Pool.	Capacity in gallons.	Period of complete turnover in hours.	Rate of filtration in gallons per hr. per sq. ft. of filtering surface.	Free Chlorine in parts per million.	Colonies in 1 c.c. of water growing in 2 days on Agar at 37°.	B. Coli.
GROUP I. Pools in which the chlorine is added continuously during the whole time of circulation and filtration and in sufficient quantity.	1	100,000	$6\frac{3}{4}$	167	0·6 at 8 a.m., 0·2 at 2 p.m., less than 0·1 at 4 p.m. time of sample.	80	Absent in 50 c.c.
	2	70,000	$6\frac{3}{4}$	167	0·4	390	Absent in 50 c.c.
	3	60,000	$3\frac{3}{4}$	430	0·8	10	Absent in 50 c.c.
	4	104,000	$6\frac{1}{2}$	430	1·3	Sterile	Absent in 50 c.c.
	5	382,000	$9\frac{1}{2}$	470	0·2 (1·3 in water entering bath)	6	Absent in 10 c.c., the largest sample taken.
	6	120,000	$5\frac{1}{4}$	470	1·3	Sterile	Sterile.
	7	60,000	$3\frac{1}{4}$	390	0·7	Sterile	Sterile.
	8	85,000	$4\frac{1}{4}$	470	0·5	Sterile	Sterile.
GROUP II. A pool in which, although chlorine is added continuously, the quantity is insufficient.	9	60,000	3	470	0·01 a faint trace	700	Present in 5 c.c. Absent in 1 c.c.
GROUP III. Pools in which continuous chlorination has been abandoned, (owing to unsatisfactory feeding apparatus and absence of apparatus for testing) and chlorine is added only (1) at night after bathing has ceased, or (2) at night and in the morning before bathing has commenced	10	82,000	4	410	Nil	175,000	Present in 1 c.c.
	11	100,000	5	420	Nil	43,000	Present in 1 c.c.
	12	94,000	$4\frac{3}{4}$	420	Nil	11,000	Present in 1 c.c.
	13	120,000	6	155	Nil	+ 3,000*	Present in 0·1 c.c.
	14	45,000	6	155	A faint trace	+ 4,000*	Present in 10 c.c. Absent in 5 c.c.
	15	45,000	6	155	A faint trace	5,000*	Present in 50 c.c. Absent in 5 c.c.
	16	45,000	6	155	A faint trace	5,000*	Present in 10 c.c. Absent in 5 c.c.
	17	82,000	4	410	Under 0·1	5,000*	Present in 10 c.c. Absent in 5 c.c.
	18	100,000	5	420	A faint trace ? under 0·05	+ 10,000*	Present in 1 c.c. Absent in 0·1 c.c.
	19	94,000	$4\frac{3}{4}$	420	A faint trace	4,000*	Present in 1 c.c. Absent in 0·1 c.c.

* Plates too crowded for accurate estimate.

In eight of these the counts were very good, in six the water being practically sterile. In only one of the pools (No. 9 on the table) thus chlorinated, in an instance in which the responsible officer had no free chlorine testing apparatus for his guidance and the free chlorine content had fallen to almost nothing, was a sample found to yield a somewhat indifferent bacteriological result.

In the other ten pools (although the plants had been provided with apparatus for it) continuous administration of chlorine had been abandoned either because the feeding apparatus was not satisfactory, or owing to the staff not being provided with testing apparatus complaints of over dosage had arisen, or from other causes, and instead of continuous administration a system of adding chlorine (in the form of 10 per cent. solutions) had been adopted whereby the chlorine solution was being added either in one dose at night after bathing and filtration had ceased, or in two doses, one at night after bathing, and one in the early morning some time before bathing had begun.

It will be observed that all the samples from such pools are unsatisfactory, whilst some are very bad. A study of the table will show that it is not make of filter or rate of filtration or even period of complete turnover which is the essential factor in keeping a pure germ-free water, but that the free chlorine decides the count, so long as the water is clear and free from particulate matter. It seems, however, that a short turnover period makes it easier to keep the chlorine content within the desired limits without complaints and is in any case highly desirable. The time of heaviest bathing or peak load is undoubtedly the proper time to take samples and this is generally in the afternoon or evening.

In the case of one or two of the pools in which the administration of chlorine was not continuous, and in which the results of afternoon samples were the least satisfactory, it is instructive to note samples had been taken some months before by the Medical Officer of Health, samples which had given excellent results. A false sense of security was thus produced by these samples owing to their having been taken early in the morning, for afternoon samples on two occasions showed that although the system of adding the chlorine only at night resulted in a water comparatively free from living organisms with which to start the day, yet this water contained insufficient residual chlorine to cope with the bacterial pollution introduced by the many bathers who entered during the day. The bacteria thus introduced no doubt multiplied rapidly in the warm bath water, and by 4.0 in the afternoon after the use by the bath of some 400 bathers the pollution was sufficient to give high bacterial counts.*

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* Of the 78 samples taken in 38 Connecticut swimming pools in 1928, Mr. Warren J. Scott found a close correlation between the bacterial count per 1 c.c. on agar at 37° C. and the residual chlorine in the water of the pool, the latter determined by the orthotolidine test. Of the 44 samples with no free

It would, therefore, appear that: (1) continuous chlorination is essential for the safety of the water; (2) it is essential that the responsible official should be equipped with means for determining accurately the free chlorine in the bath; and (3) whilst efficient chlorination can be performed by other methods, the method of administration of chlorine gas in solution is the best.

The Use of Chloramine.

The use of chloramines holds out considerable promise in connection with swimming bath disinfection, owing to the prolonged effective action which is characteristic of such compounds. Filtration plant embodying this method of chlorination are now being installed in this country for the first time. The method consists in the administration of ammonia gas which is given a short period of contact before the administration of the chlorine gas.* The dose of ammonia is usually ¼ of that of the chlorine, and probably the best way to administer it in such a system as we have been describing would be to deliver the ammonia gas solution into the effluent main from the filter, before the water enters the aerator, and to place the delivery pipe for the chlorine gas solution on the same main between the aerator, and the entry to the bath. The addition of the ammonia seems to increase not only the efficacy of the chlorine, but the length of time during which it is able to produce its disinfecting action, and the method seems one less liable to produce complaint than the simple administration of chlorine. For not only is the added mixture somewhat less irritating, but the process may enable the quantity of chlorine to

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chlorine, 28 showed counts over 1,000 per 1 c.c.; of 40 samples with a free chlorine content over 0·2 parts per million of water, or over—

19 gave counts less than 10 per 1 c.c.
 5 others, counts less than 100 per 1 c.c.
 1 other, less than 200 per 1 c.c., and
 2 others, less than 500 per 1 c.c., whilst
 3 gave counts between 5,000 and 10,000 per 1 c.c.

"The reason for these exceptions," says Mr. Scott, "might be explained by non-penetration of sediment in the water by the chlorine. It is to be noted, moreover, that in no cases were organisms of the coli-aerogenes group (indicators of dangerous pollution) isolated in the presence of residual chlorine in excess of 0·2 p.p.m. It is almost always true that high bacteria counts indicate that insufficient residual chlorine was present in the pool at the time of collection of samples. The presence of residual chlorine in a swimming pool water is not only an indication that harmful bacteria have been destroyed, but it is assured that if harmful bacteria are introduced as the pool is in use, these bacteria will be immediately destroyed by the action of the chlorine; provided, of course, that an unduly large access of contamination is cared for by replenishing the chlorine supply when it is exhausted, and provided sediment is practically absent from the water." *Connecticut Health Bulletin*, Vol. 42, 9. September, 1928. Page 190.

* The reader should refer to Sir Alexander Houston's work on the subject, particularly the series of experiments in the Twentieth Research Report to the Metropolitan Water Board, pp. 77–88, and Twenty-First Report, pp. 36–38.

be diminished. Moreover, the process is well suited to swimming bath pollution, which shows a definite and constant excess of animal pollution.

Owing to the reduction in the quantity of chlorine which can probably be made with this system, the cost should not, in the long run, exceed that of the simple chlorination, but the expense of installation is, of course, somewhat greater owing to the necessity for two gas plants. We understand that this method is in successful use at Dresden (W. Olszewski*) and at Hamburg (Dr. G. Nachtigall), where, in addition, the water is filtered through two filters in series.

Mr. Joseph Race, F.I.C., whose work upon the chlorination of water supplies is well known, has kindly furnished one of us with notes on some experiments made upon sewage and swimming bath water, comparing the effect of the administration of chloramine with that of the administration of chlorine alone. Mr. Race writes:—

> For the destruction of bacteria in water, the use of ammonia in conjunction with chlorine compares most favourably with the use of chlorine alone when the water to be treated contains an appreciable amount of organic matter. The reason is that none of the chloramine is used up in the oxidation of the organic matter, whilst a considerable proportion of added chlorine or hypochlorite is invariably destroyed in this manner.
>
> My experience in Ottawa, which has been confirmed by that of Sir Alexander Houston in London, was that the proportion of the chlorine used up by the organic matter increased with the temperature, and this would indicate that a considerable amount of chlorine would be so deviated in the case of swimming pool waters that are usually heated.
>
> The effect of the use of ammonia is amply demonstrated by the following experiment. About 10 per cent. of boiled sewage was added to tap water, which was then seeded by the addition of a small quantity of fresh sewage. The original count on agar after 24 hours' incubation at 37° C. was 31,300 colonies per c.cm.
>
> The counts after treatment were :—

Contact period.	0·75 p.p.m. Cl. No ammonia.	0·75 p.p.m. Cl. 0·20 p.p.m. NH_3
1 hour.	9.600	1,750
4 hours.	8,000	450

> The following results are also instructive. These were obtained with the water that it is proposed to use in the new Amsterdam swimming pool, but after coagulation with alum and filtration, as a filter plant will be a part of the purification scheme.
>
> To the filtered water, one part of urine from a case of cystitis was added to 5,000 parts of water. It was considered that, although the dosage of contaminating matter was excessive, the conditions would simulate more closely those obtaining in the pool than the use of the usual laboratory cultures.

	A.	B.
Chlorine	0·2 p.p.m.	0·4 p.p.m.
Ammonia	0·05 ,,	0·1 ,,
B. coli added ..	4,500 per c.c.	4,500 per c.c.
B. coli after 4 hours	88 ,,	2 ,,
B. coli after 24 hours	2 ,,	0

* Chemiker Zeitung, 1928. 14.

At this stage, *i.e.*, after 24 hours had elapsed, a similar dose of fresh urine was added. The *B. coli* in this was sufficient to increase the *coli* content of the water by 4,800 per c.cm. Counts were made after 4, 6 and 24 hours.

	A.	B.
After 4 hours	4,800	11
,, 6 ,, ...	No change.	5
,, 24 ,, ...	Large increase	None in 1 c.c.

With 0·2 p.p.m. the germicidal action was evidently at an end, but with the larger dose the residual chloramine was capable of dealing with a further increment of pollution.

These results, which are confirmatory of those obtained by Dr. Idzerda of the University of Utrecht, whilst working on the same water, but with fæcal suspensions as the added pollution, have led to the installation of a chloramine plant for the N.V. Overdekte Bad-en-Zweminrichting "Het Sportfondsenbad," Amsterdam. This plant, which is the first one manufactured in this country for the purification of swimming pool water by the use of chloramine, has been designed and manufactured by the Paterson Engineering Co., of London.

Provision has also been made for the use of a small quantity of sodium carbonate, if the use of an alkali is found to be desirable.

In Germany, following the experimental work of W. Olszewski at Dresden (Chemiker-Zeitung, 1927, Nr. 28 and 1928, Nr. 14), chloramine installations have been made in the Guntzbad and the Georg Arnhold-Bad in Dresden and a pool in Halle.

Olszewski, in the latter of the two articles cited above, obtains better experimental results with the addition of a small quantity of sodium carbonate. Evidently the object is to neutralise the acid formed by the reaction of ammonia and chlorine

$$NH_3 + Cl_2 = NH_2\,Cl + HCl,$$

and which may tend to the destruction of the chloramine.

If a water has a sufficiently high alkalinity I should think that the addition of alkali is redundant, but I can well imagine a case in which the low natural alkalinity of a water may be so reduced by repeated coagulation with alum as to provide a medium in which chloramine may be unstable. These soft waters, usually derived from upland gathering grounds, are in a class by themselves and often require the addition of an alkali before treating with alum.

In experimenting with the chloramine treatment it must be borne in mind that a comparatively strong solution of chloramine cannot be prepared by adding ammonia to either a chlorine solution or to one of a hypochlorite.

At laboratory temperatures I found that the maximum stable concentration was with 120 p.p.m. of chlorine and 30 p.p.m. of ammonia. Higher values merely lead to loss of available germicidal material.

The better way is to add the ammonia first at some point in the purification system, before aeration for example, and the chlorine solution later. The ammonia should always be added before, and not after, the chlorine.

Chloramine has been in use for 12 years in Ottawa for the city supply, and for about 10 years in Denver, Colorado.

In England it has been used for several years by the Metropolitan Water Board—particulars in various reports* by Sir Alexander Houston —and for some months at Belfast.

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* Especially Twenty-first Annual Report to the Metropolitan Water Board, Sir Alex. Houston, 1927, p. 36, but also Twentieth Annual Report, 1926, p. 42.

Ornstein of Berlin (Chlorator-Gesellachaft) tells me that he has furnished several installations to German cities for the potable supplies.

I also note that a mixture of sodium hypochlorite and ammonia is in use in the swimming pool at Rosswein, Germany.

The methods of testing to ascertain the amount of free chlorine will be discussed in a later section.

The chlorination of the effluent water from the filters must be so adjusted that the water in any part of the swimming bath will show a free chlorine content of at least 0·2 parts per million. This amount will ensure that the bacterial count will be low and that *B. Coli** will be practically absent. By slightly increasing the quantity of free chlorine an almost sterile water can quite easily be produced, without any perceptible odour of chlorine or any smarting of the eyes. It is advisable, however, as has already been stated, that the free chlorine in the bath should not exceed 0·5 parts per million. This is the standard originally suggested by the American Association for promoting hygiene in public baths in 1922, and it seems to have borne well the test of time. The result of the present series of investigations was to confirm this standard. When the filtration and aeration are also efficient this degree of chlorination will give on the one hand a bacterial degree of purity equal to that of most drinking waters, and on the other hand a bright and sparkling water with entire freedom from complaint.

In addition to its germicidal action the use of chlorine prevents the growth of algae, which often cause trouble in indoor baths by unsightly and slippery green growths on the sides and bottom of the bath, and which may discolour the water to a serious extent even in a few hours.

With open-air baths trouble from algae is more pronounced and sometimes leads to such complete opacity of the water that it is not possible to see the bottom at the shallow end. Several fatal accidents from drowning have recently resulted from opaque water. An additional advantage of continuous chlorination is the doing away of that musty smell which used to haunt many of the old fashioned swimming baths.

Tests for free chlorine.

To equip a swimming pool with a modern purification plant (using the method of continuous filtration and chlorination)

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* See Sir Alexander Houston Thirteenth Research Report M.W.B., p. 9. Tonney, Greer, and Danforth studying the action of chlorine on cultures in distilled water, found that *B. Coli* proved on the whole to be more resistant to free chlorine than the other organisms studied, which included *B. typhosus, paratyphosus A and B, streptococcus, hæmolyticus and fæcalus, etc.* None of the strains showed any appreciable reduction in number when exposed to 0·1 p.p.m. of chlorine. Nine strains were killed by 0·15 p.p.m. of chlorine, ten strains required 0·2 p.p.m., and nine required exposure for 15 seconds to 0·25 p.p.m. of chlorine for their complete destruction. *American Journal of Public Health*, October, 1928, page 1,261.

without, at the same time, providing the officer responsible for its working with the apparatus and the skill requisite for determining the presence and amount of the free chlorine in the water (1) of the filter effluent, and (2), even more important, in the pool itself, is but lost endeavour, a wasteful parsimony which will ensure trouble.

The determination of free chlorine in bath water presents no practical difficulty, as the confusion, theoretically possible owing to oxidising substances such as nitrites and ferric iron producing similar colour reactions to those produced by chlorine, does not in practice arise when dealing with bath water to which it is known that considerable quantities of free chlorine are being added, and in which nitrites, even if present, are only in extremely minute quantities

Two methods at present hold the field—the iodide and starch method and the orthotolidine.

(a) *Starch and iodide test.*

To perform this test two white cups, or preferably two glass beakers, of which the bottoms have been painted externally with white enamel, are filled with water to be tested; to each a small crystal of potassium iodide is added, and dissolved by stirring with a clean glass rod. When the solution is complete, one or two drops of a clear starch solution (amylum B.P.) is added to the one beaker; the other being used as a control; if free chlorine is present in the water a blue colour develops in the beaker to which the starch has been added, and by using this method of comparison in a good light a strength of 0·1 parts per million of free chlorine can usually be detected, whilst 0·2 parts per million will give a very definite tinge. Whilst this method is a rough one it may be said that if the water from the deep end of a bath will give an undoubted tinge of blue with this test, and if a bacteriological analysis be made of the water at the same time, the bacterial count will usually be found entirely satisfactory. This method is used by the keepers of those of the L.C.C. open-air baths which are purified on the filtration system and Mr. Coste, chemist to the L.C.C., has devised a useful method whereby the starch solution may be preserved for a long time free from moulds, i.e., by keeping a small coil of bright copper wire in the bottle.

(b) *Orthotolidine method.*

This method appears to have been first suggested by E. B. Phelps, who used a solution of orthotolidine in acetic acid. According to Phelps a yellow colour could be detected by this method in the presence of 0·05 parts of chlorine per million. Dittoe and Van Buskirk working at this method, were followed by Ellms and Hauser,* who improved it by using hydrochloric acid instead of

* J. W. Ellms and S. J. Hauser (Jour. of Ind. and Eng. Chem. 1913, 5, 914–916).

acetic acid. The resulting solution does not deteriorate on standing. A convenient strength is one gram of orthotolidine in a thousand c.c. of 10 per cent. hydrochloric acid, 1 c.c. of this solution being added to 100 c.c. of the water to be tested.

It is said that 0·005 parts per million can thus be detected.

Several neat forms of apparatus for using this method are now made by various firms, some using standard solutions of bichromate and copper sulphate for comparison, others using tintometer glass of varying depth of colour. One of the latter forms of apparatus measuring only 8½ ins. by 5¼ ins. by 2 ins. has been fully tested and found rapid and reliable, while its easier portability has, for the purpose of this report, rendered it more convenient than larger and heavier forms of apparatus in which standard solutions are used for comparison, though the latter may perhaps give finer gradations, and are admirable when extreme portability is not essential.

The provision of a reliable apparatus for the determination of the free chlorine is an essential part of a modern purification plant, and routine tests should be made at least three times a day of the water of every pool, and accurate records kept. If, as we believe, a free chlorine content of between 0·2 and 0·5 parts per million in the water of the pool, provided the water be also clear, indicates a bacterial count almost equal to the standard of drinking water, together with freedom from complaints of taste and smarting eyes, then the advantages to be derived from the frequent use of this test, which can be carried out in five minutes by any intelligent person will be obvious. Its use affords a method of estimating the bacterial safety of the water, easier, swifter, and more effective than the difficult method of bacteriological determination, for which samples must be taken in the most careful manner, and from which results cannot be obtained under at least 48 hours, by which time the condition of the water in the pool, has, of course, entirely changed.

VII. ALKALINITY.

The water of a swimming bath purified by continuous filtration must always be kept alkaline in reaction, so as to neutralise the acids formed from the coagulant alum (or alumino-ferric) and the added chlorine. It is almost impossible to get clear water unless this alkaline reaction is maintained, as the coagulant film will not be formed on the sand, and the water in the bath will be hazy with particles.

The water supplied to most indoor swimming baths has usually some natural alkalinity, and as in most filtration plants the filters are washed with bath water, and this loss is made up with fresh main water, the make-up water is sometimes sufficient to keep the bath water at the requisite slight alkalinity. Owing, however,

to the acidifying action of the alum or alumino-ferric, and in a slighter degree to that of the chlorine, it is usually necessary to add either lime, or soda ash to the water before it enters the filters. Roughly, about half as much soda ash by weight as alum should be added to keep the pool sufficiently alkaline.

A rough test for a sufficient degree of alkalinity is to keep the water just sufficiently alkaline to produce the faintest pink colour, when two or three drops of phenolphthalein solution (1 per cent. in rectified spirit) are added to about 100 c.c. of water.

The State Department of Health of Connecticut* considers that the desirable degree of alkalinity is to keep between a bicarbonate of soda alkalinity of 10 to 20 parts per million (determined by the methyl orange test), and that this is sufficient alike for efficient filtration and for the avoidance of smarting eyes. Complaints of smarting eyes may be caused either by too much alum, too much lime, or too much chlorine, though the symptom is usually attributed to the last named, often incorrectly.

Recently, however, simple colorimetric apparatus for determining the hydrogen ion concentration (using the same tubes as in the free chlorine test) have been introduced by various firms, and are very simple to work. A small amount of a standard solution of chemical† is added to a standard amount of water, and comparison is made with colour standards, either solutions or tintometer glasses. According to Warren J. Scott, the p H value should lie between 7 and 7·6, but 8 is a more usual figure in London baths, and is probably not too high (J. H. Coste).

The provision of apparatus for measuring the right degree of alkalinity is as necessary for the successful working of the filters with respect to clarity, as is the provision of apparatus for measuring the free chlorine with regard to bacteriological purity.

Too little alkalinity will give an unsatisfactory water, hazy and dirty looking, and difficult to chlorinate, and greatly increases the risk of smarting eyes. On the other hand, too much alkalinity may also interfere with proper filtration, and may allow colour to pass through the filters.

Too much lime we have found on one or two occasions to give rise to complaints of smarting eyes, and the water in the bath should never contain lime as caustic alkali.

VIII. OTHER DETAILS OF THE CONTINUOUS SYSTEM.

Inlets for the filtered water.

The purified and re-aerated water has now to re-enter the bath at the shallow end. The best arrangement is to provide several

* Connecticut Health Bulletin 42, 9, p. 191, Sept., 1928.

† Phenol Red is the indicator generally used; this gives a pale buff colour at p H 6.5 changing to a deep rose colour at p H 8.

submerged inlets, the number being determined by the size and shape of the bath, so that currents of pure water flow in the direction of the outlets, leaving no stagnant corners or "pockets" where impure water might linger without change.

With the idea of keeping the water more uniformly chlorinated during its passage along the bath, some recent designs embody a number of inlets along the sides of the bath in addition to those at the shallow end. All these inlets are fitted with valves to control the flow, and it is hoped that by careful regulation an efficient method of supplying the bath will be arrived at.

So far this system has not been fully tested, but the results are awaited with interest.

Meters and gauges.

No filter plant is complete without some simple apparatus for indicating the rate of flow of the water delivered from the pump. Expensive meters are hardly necessary either to measure the quantity passing through the filters or the amount of wash water used, but it is necessary that the delivery of the pump should be checked from time to time.

Pressure gauges on the filters showing when the head has increased to the point when washing is required should be of at least 6 inches in diameter, and test cocks and visible flow indicators to allow the operator to watch the washing of the filters are necessary.

Scales for weighing chemicals and the chlorine cylinders should be supplied, and every bath superintendent should keep a log book with daily records of the performance of the filters, and the result of tests.

The time has arrived when the running and maintenance costs of these filter plants should be recorded. Specifications should call for particulars of power consumption, as the possible lowering of the standards of efficiency, due to keen competition in tendering, can only be determined by a comparison of the running costs of the different makes of plant.

Guarantees of the efficient working of Filter Plants.

In drawing up a specification on which tenders for a filter plant are called, it is desirable that the guarantees in respect of the purification and heating of the water should be set out by the engineer who is responsible for ordering the plant. The old method of calling for guarantees from the makers served its purpose when there was little experience of the performance of bath filtration plants, but it led to many curious claims for efficiency in different directions, and incidentally to the confused thinking which seems responsible for some of the clauses in many specifications relating to bath purification plants.

One point which calls for settlement is whether the guarantees

should apply to the water in the bath, or to the water as it is delivered into the bath (*i.e.*, the effluent) from the filter, or to both.

It is obvious that samples of water taken from a pool during or after use by bathers are not suitable for purposes of guarantee for no filter can be blamed for a bad sample if the water sampled has not passed through the filter since it was polluted. It appears therefore, that gurantees of water purification should apply only to the filtered water (effluent) as it enters the bath, but that those guarantees should cover the effluent at all times, and under all conditions of bathing. If this is clearly understood there will be no need for the makers to safeguard themselves by inserting clauses to the effect that the plant shall be worked after bathing has ceased, until the water is in a condition for taking samples. Almost any plant can produce good results with such a condition attached to it.

Similarly, guarantees which call for long and expensive tests and analyses or for special apparatus may be carried out once in the very early life of the plant, but these will not tell what the plant is doing every day under working conditions.

A guarantee ensuring a satisfactory effluent water having been secured and also a turnover period sufficiently short for the capacity of the bath in relation to the number of bathers on "peak" days, there will be some probability that the water, from the time it enters the bath as clear chlorinated water will not have become unreasonably turbid or dangerously polluted by the time it leaves the bath at the deep end.

The sections dealing with chlorination and filtered water inlets show the steps that are now being taken to deal with bacterial pollution by bathers as the water passes through the bath without having recourse to undesirably large doses of chlorine.

It is considered that if the conditions which have been stated as to the continuous chlorination of the filtrate are carried out, the necessity for laying down bacteriological guarantees does not arise.

Clarity is very important and the filter effluent should maintain a standard at all times, and under all conditions of bathing as long as the filter plant is being worked properly.

The difficulty with regard to clarity is to know what degree of perfection can be attained without adding unduly to the cost of the plant by increasing its size. It is not an easy matter to devise a simple apparatus for testing clarity, but fortunately this difficulty seems now about to be overcome, as have been the difficulties of devising simple yet accurate apparatus for measuring chlorine and alkalinity.

The standards for clarity in a swimming bath water as usually guaranteed have either to be as ascertained from the inspection of a column of water in a tube 2 feet long, or, by the visibility of a 19 S.W.G. platinum wire when viewed through 6 feet of water. Neither of these are very helpful, for the former is not checked

against any standard and the latter can only be judged by the water at the deep end of the bath which is obviously unfair to the filter.

Colour.—Some guarantees call for a standard of colour of 15 on the Platinum Cobalt Scale (Loch Katrine=10.) The usual colouring matter met with is either due to peaty waters or to dye from bathing costumes. Treatment with a coagulant before filtration and chlorination will remove such colours, and unless there are special reasons, guarantees for reduction of colour do not appear to be necessary.

Chemical Guarantees.—There is no evidence at present to show that water circulated through an efficient swimming bath purification plant deteriorates chemically to a degree which calls for precautions. Excessive alkalinity is to be avoided but otherwise guarantees of chemical content which involve expensive analyses appear unnecessary.

It is considered, therefore, that provided always that the turnover period is sufficiently short, guarantees would be sufficient which call for a water entering the bath at all times and under all conditions of bathing which shall meet the following requirements.

(1) The water issuing from the plant shall contain not more than 0·5 parts, and not less than 0·2 parts per million of free chlorine;

(2) be definitely alkaline to methyl orange, but free from caustic alkalinity;

(3) be of a clarity so that a 19 S.W.G. platinum wire can be seen through a depth of six feet;*

(4) fully aerated, sparkling and attractive in appearance.

Guarantees with regard to the quantity of wash water used as a percentage of the total quantity of water filtered are demanded from time to time. A guarantee of this description can only be valid if determined over a period of several months, as the amount of washing varies according to the use and pollution of the bath. Unless too an accurate meter is provided to measure the wash water very little can be expected from a guarantee of this nature.

Guarantees of power consumption during a day's run are important.

Cleansing of the Bottom of the Pool.

In a bath provided with a continuous purification system it is necessary to remove any sediment which may deposit on the bottom of the bath.

This is done either by brushing with a special long handled brush or by a suction cleaner, run on rubber-tyred wheels so that the slot is about half an inch above the surface of the bottom, fitted with a

* It is hoped that a simple apparatus for determining the clarity of water will shortly be available.

long handle, or tow ropes and with a flexible hose. This hose can be connected at the side of the bath below the surface of the water to the suction main of the pump, the flow from the pool outlet being either stopped or throttled down to permit the pump to exert a full suction on the cleaner. Scouring of the sides is usually done with a brush, and any visible scum is removed by a long skimming pole.

Prevention of pollution entering the pool.

Much can be done in the design of a swimming bath to assist the work of the filters in keeping the bath clean. The provision of a sufficient number of shower baths, foot baths and lavatories will do much to prevent pollution of the bath water. A preliminary cleansing shower and foot-bath should be made compulsory before the bather enters the pool.

Scum troughs placed round a bath are useful for bathers who must spit, and they help to prevent dust collecting as scum on the water surface. Consideration should be given in the choice of a site for a bath to one which is as far away as possible from dusty roads, or smoking chimneys, and here it may be mentioned that the siting of baths alongside refuse incinerators, as is sometimes done to secure cheap fuel, leads to constant trouble from dirt and dust.

Surrounds.

If possible, the dressing arrangements should preclude the use of the bath surrounds by bathers before removing their boots or by spectators. These surrounds should slope away from the bath and drain to a gutter. The actual material of which swimming bath surrounds should be made has never been settled and ought to be the subject of a careful investigation. Most materials when wet become slippery to bare feet and many minor accidents are the consequence.

Ribbed tiles are said to hurt the foot, whilst matting becomes smelly, and cannot be kept clean. There is, perhaps, an opening for use of a ribbed rubber flooring in this position, but it is not certain that such material will adhere properly, or that it is free from "spreading."

IX. SUMMARY.

1. Owing to the greatly enhanced popularity of swimming of recent years the demand for swimming bath facilities has greatly increased, and the accommodation, nearly always inadequate in hot weather, still falls far short of the demand. Increased provision, especially for women and for mixed bathing, is urgently required. New bathing pools are being constructed in many places, and the purity of their water is a matter of considerable importance to the public health.

2. The danger of the transmission of disease by polluted water in swimming baths has sometimes been exaggerated, but it does exist. All public swimming baths should be filled with water which is not only clear, sparkling, and attractive, but is also practically free from germs of disease, or bacteria of excremental origin. This should apply in equal measure to the swimming baths which, though not public, are used by many persons such as school swimming baths.

3. For swimming pools of artificial construction, both indoor and outdoor, filled with water from the main supply, the method of continuous rapid filtration, combined with continuous chlorination and aeration, properly carried out with modern plant of adequate size, is capable* of keeping the water clear, sparkling and attractive in appearance, and of a bacterial purity approximating to that of drinking water. In addition it affords important economies in cost of water and heating.

4. This method of purification has advantages over the fill-and-empty system, even when the refilling in the latter case is done daily. When the refilling is not done daily, the advantages of the continuous filtration-chlorination method of purification become overwhelming, and, as daily refilling (besides making, in some places, large demands upon the water supply at inconvenient times) is usually financially impracticable, it follows that, except in very unusual circumstances, artificial bathing pools should always be equipped with adequate continuous purification plants.

5. To maintain water such as has been described in the second paragraph many conditions must be fulfilled alike by the plant, and by the staff which operate it. The following are especially important.

6. The period of complete circulation or "turnover" should be short, i.e., for covered baths up to 150,000 gallons' capacity, it should not be more than four hours, except in cases where the bath is little used. For example, if the bath contains 100,000 gallons, the pumps and filters should be capable of dealing with at least 25,000 gallons per hour.

7. The rate of filtration should not be so excessive as to allow the passage of unclarified water.

8. The appropriate and precise dosage of coagulant previous to filtration is necessary, and the water should always have a slight but definite degree of alkalinity—sufficient, that is, to show an alkaline reaction to methyl orange. Accurate dosage of coagulant and alkali is essential to the maintenance of the proper

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* Provided, of course, that the pool is not hopelessly overcrowded—there is a limit, but it would be reached sooner in such circumstances with the fill-and-empty system even with a perfectly fresh morning water.

standard of clarity and appearance, and to the avoidance of complaints of smarting eyes. Reliable and easily regulated dosing and mixing apparatus is therefore required.

9. Chlorination should be continuous during the whole period of bathing, and working the filter plant, and the dosage must be sufficient to maintain a strength of free chlorine in the water of the *pool* itself which shall not be less than 0·2 parts of chlorine per million of water, or greater than 0·5 parts per million. Water with this free chlorine content, which has been efficiently clarified by filtration, will give satisfactory bacteriological counts approximating to drinking water standards.

10. The free chlorine content can be easily and accurately determined by simple apparatus based upon the orthotolidine test, and similar apparatus can be used with equal facility for determining the alkalinity. It is essential for the proper working of the plant that tests should be made at frequent intervals, both of the effluent water from the filters, and of the pool water. Three times a day should be regarded as a minimum routine for such tests, and accurate records showing the number of bathers, the amount of water pumped, chemicals used, free chlorine content, and alkalinity should be kept.

11. Chlorination can be performed by properly constructed plants adapted either for the use of chloride of lime, or the solutions of chlorine, or for chlorine gas. Plants using chlorine gas will, however, usually be found the most satisfactory. In these, dosage can be instantly adjusted, and accurately measured, and there is no depreciation of chlorine strength during storage. There is also probably less danger of complaints due to taste, smell, or smarting eyes.

12. The success of the purification in such a system depends not only upon the design, sound construction, handiness and easy accessibility of the plant, but also in equal measure upon the care and skill of those operating the plant. It is unfair to a bath superintendent and his staff to expect them successfully to handle such a purification plant unless they have been given a sufficient course of instruction in the working of the plant and of the requisite instruments for testing the chlorine content, alkalinity and clarity.

13. The foregoing paragraphs deal with the purification of the water, but the prevention of unnecessary pollution entering the water will greatly assist the operation of the purification plant, and the following points require special attention.

14. The provision of an adequate number of shower baths and foot-baths, provided with both hot and cold water (in a proper adjustable mixing apparatus) and with soap, and placed at con-

venient points round the bath, is essential. Before entering the pool all bathers should take a shower bath, as well as a foot bath.

15. Ample and convenient lavatory accommodation is also required. Separate accommodation for each sex should be provided in the case of a pool which may be used for mixed bathing.

16. All side walks surrounding the pool should be of sufficient width, and sloped gently away from the pool to properly placed drains. The best material for such side walks, *i.e.*, impervious, durable, easily cleaned, and not slippery for wet feet, has not yet been determined, and the subject deserves careful investigation. Slippery side walks are the cause of many accidents.

17. Much of the avoidable dirt which finds its way into the pool is brought from the side walks surrounding the pool, and is derived from the shoes of bathers entering and leaving their boxes, and from those of spectators. If possible, therefore, the dressing box arrangements should be such as will preclude the use of the side walks by bathers, previous to undressing, and other stands or galleries should be provided for spectators. Dressing boxes should be commodious, well lighted and ventilated, and their design and material should be such as to render cleaning down and disinfection an easy matter. The bath hall should be well ventilated and lighted and a plentiful supply of outside air and direct sunlight should have access to it.

18. Costumes are the source of considerable dirt and discoloration in the pool. They therefore, as well as towels, should be washed with hot water and soap, as well as sterilized after use; both should be provided in ample numbers so that there is a sufficient margin to enable the laundry to wash, sterilize and dry every article in times of rush attendance, as during a heat wave. Merely to dry towels and costumes before re-use, as is sometimes done in such periods, is a disgusting practice likely to transmit infection.

19. Figures obtained where filter plants have been installed have shown large savings on working costs after all charges, including loan charges, had been met. This desirable financial position was accompanied by considerable increase in the popularity of the baths, part of which was no doubt due to the never failing clarity and attractiveness of the water. Every day should be a clean water day.

20. The chloramine modification of the process of chlorination has not yet been tried in swimming baths in England, though baths equipped with purification plants using it are in course of construction. From experience with drinking water purification, however, and with swimming baths in Germany it seems reasonable to hope that by its adoption an equal sterilization might be attained

with a lessened dosage of chlorine, and a lessened liability to complaints of taste, smell or smarting eyes.

21. In Section V where filtration plants are described, emphasis has been placed on the desirability of full consideration being given when a specification for plant is being drawn up, not only to the first cost, but the questions of efficiency and cost of running.

The design of these installations has, of course, not attained finality, and progress can only be made if makers are encouraged to produce plant which will show low running costs and call for as few repairs and renewals as possible. Such progress will, however, be slow unless proper attention is given to the question, and adequate records of running expenses and repairs are kept.

Useful records are generally to be found in the Baths Superintendent's Office as to the number of bathers, etc. ; but there is also the need for a detailed record of the performance of the filtration plant, and it is suggested that "log books" should be kept in which figures and facts, exclusively relating to such installations, should be entered daily. From such figures a useful abstract can be prepared at the end of each year or bathing session.

A daily log might record among other items:—

(1) The hours during which the plant is working.
(2) The washing of each unit and the time taken.
(3) The power consumed during each 24 hours for the filters only.
(4) The weight of each chemical used including the liquid chlorine gas.
(5) The amount of make-up water taken from the mains.
(6) Notes on the alkalinity, clarity and chlorine content of the bath water.
(7) Notes on any unusual condition observed in the water in the bath and of any defects or difficulties experienced with the filter plant.

From such logs it should be possible to arrive at the cost of water, power, chemicals, chlorination and maintenance per million gallons of water filtered, in addition to valuable data in connection with the process of bath filtration.

The Baths Superintendents' Association take great interest in all problems connected with bathing; and if the Association could take the lead in devising a satisfactory model log sheet, it would add greatly to the usefulness of the work of the Association.

In conclusion, acknowledgment is made of the numerous chemical and bacteriological analyses made by the staff of the Government Chemist, and of the bacteriological work of Dr. Griffith and Dr. Scott of the Pathological Laboratory of the Ministry of Health, upon which the report is based. Much kind help has also been

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